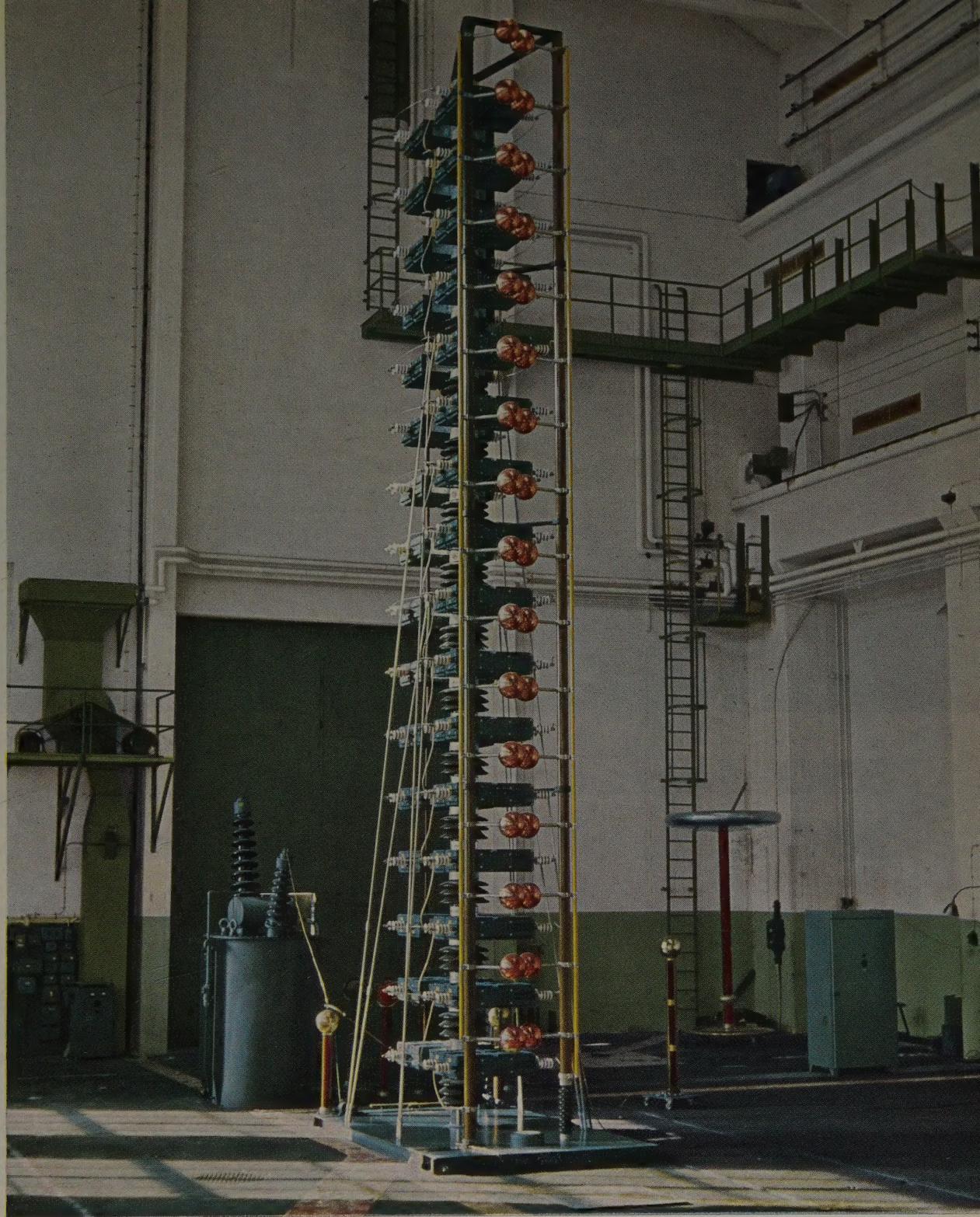




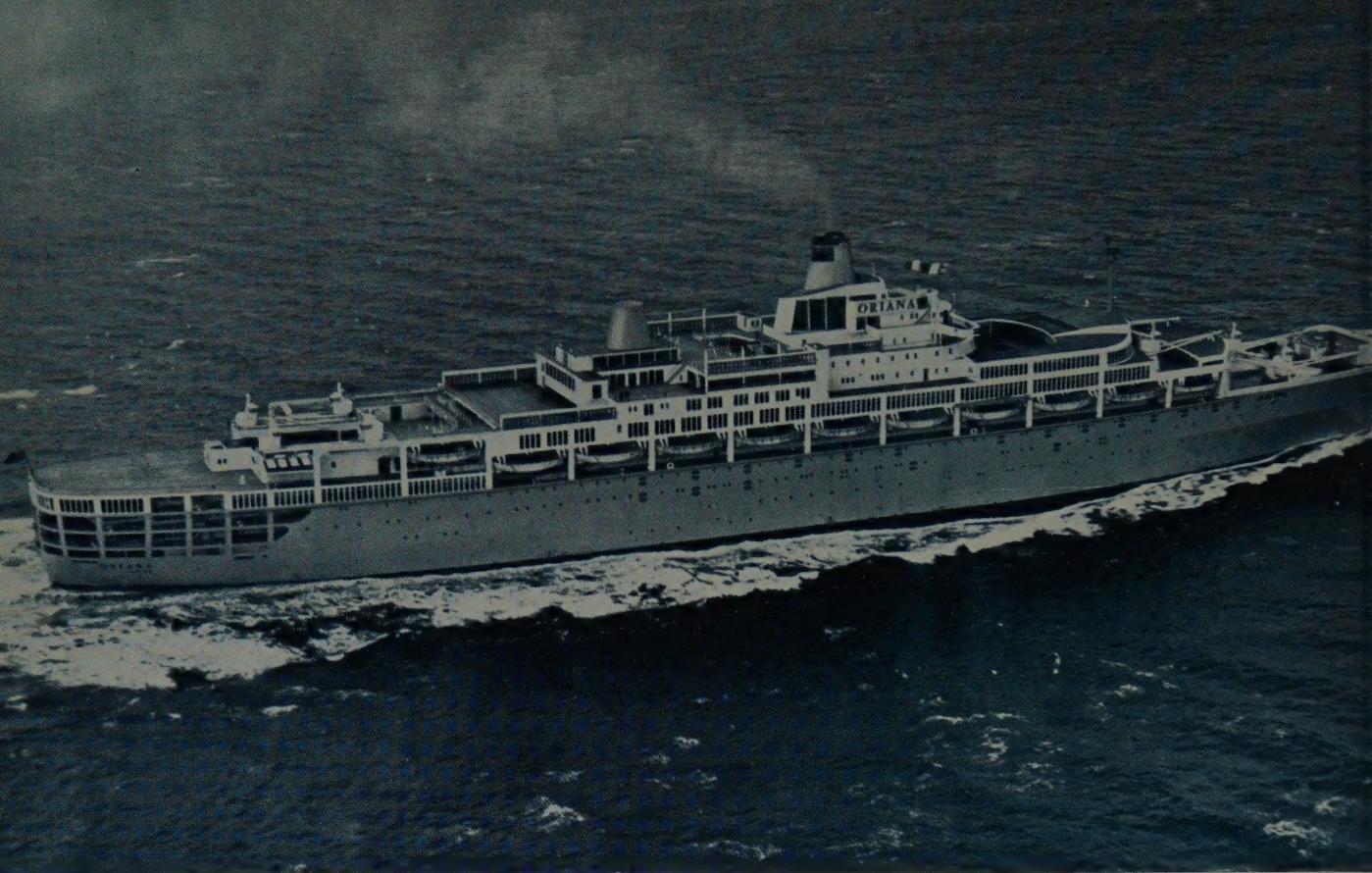
Sixteen-stage impulse generator for 3,200 kV, 140 kW, designed and built by Asea. The capacitors were supplied by Liljeholmens Kabelfabrik, Stockholm. (F 1130)

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650 deck cranes and 250 sets of a.c. equipment

have been, or are to be, supplied by ASEA for use on board ships.

ASEA were pioneers in the development of deck cranes and their new designs have ensured that they still maintain a leading position in this field.

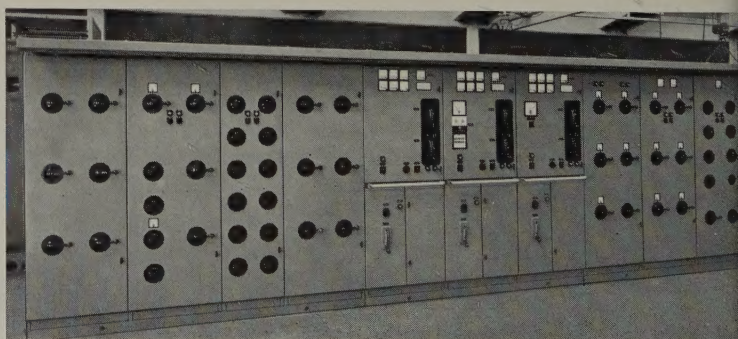
The illustration above shows one of the most interesting vessels launched last year, P & O-Orient Lines' 40,000-ton S/S Oriana, which is equipped with eight ASEA 5-ton deck cranes. Many shipping lines throughout the world have found that it is advantageous to provide their vessels with ASEA cranes. These

deck cranes are also manufactured in the USA under licence.

ASEA were also in the forefront of development which led to the adoption of alternating current on ships and they have greatly contributed to the continuously increasing use of this system at sea.

In recent years, the many advantages, including economic ones, have been noted and appreciated by ship-owners in the many different countries in which ASEA have supplied marine a.c. equipment.

If you are increasing, or modernising your tonnage, it would pay you to consult us on the electrical equipment. We should be delighted to provide you with further information and to assist you in any way we can.



ASEA

HIGH-VOLTAGE IMPULSE-TESTING EQUIPMENT

gen Fryxell, General Development Department for Transformers, Ludvika

U.D.C. 621.319.53
Asea Reg. 496

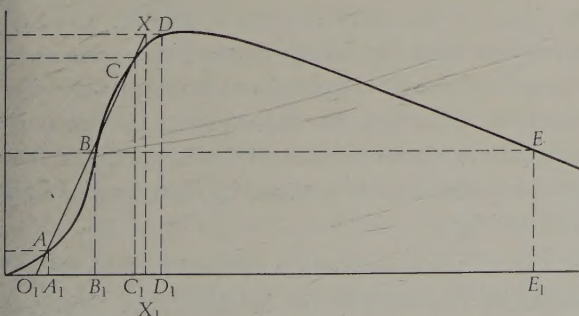
During recent years impulse testing has become increasingly more important and this has led to new demands on the testing equipment. Modern impulse generators must be very adaptable to suit different types of test object. Asea can now supply complete sets of impulse-testing equipment that are highly flexible and reliable in service. Some special features of the Asea impulse-testing equipment are described.

Impulse tests are performed on most high-voltage apparatuses to check their ability to withstand lightning over-voltages. From the beginning the impulse test was considered to be a very complicated procedure, and such tests were generally performed only in special laboratories. Nowadays, however, the impulse test is very common.

Since impulse tests are now more often performed, the requirements on the impulse generator have changed. From being a very special and sensitive item of laboratory equipment, the impulse generator is nowadays in common use and is easy to handle.

IMPULSE TESTING

Fig. 1 shows the general shape of an impulse voltage that is used for tests. The rising part of the impulse (t_1) is called the front and the falling part the tail. The time E , in Fig. 1, is defined as the time to half-value (t_2). The impulse shape has been fixed in national standard specifications at certain nominal values. The impulse shape is expressed by t_1/t_2 , with the times given in microseconds. In Europe the recommended impulse shape is 1/50.



X_1 - front time, t_1
 E_1 - time to half-value, t_2

1. General shape of an impulse voltage. (Fr 723)

The impulse voltage is usually generated by a number of capacitors, connected in parallel during charging and in series during discharging. Fig. 2 shows a schematic diagram of an impulse generator built in n stages. The capacitors are charged in parallel over high-ohmic resistors R from a d.c. source. During discharging the capacitors are automatically connected in series by means of sphere gaps. Resistors and capacitors are used in order to obtain the desired impulse shape. Fig. 3 gives a schematic impulse circuit with a simplified impulse generator, external impulse-shaping components and a test object, indicated as a capacitance in parallel with an inductance.

The front time of the impulse voltage on the test object can be roughly calculated as

$$t_1 \approx 2.5 (R_i + R_e) C_T \quad (1)$$

and the time to half-value as

$$t_2 \approx \sqrt{L_T \cdot C_g} \quad (2)$$

or, if L_T is high compared to R_d and R_p ,

$$t_2 \approx 0.7 C_g \frac{R_p \cdot R_d}{R_p + R_d} \quad (3)$$

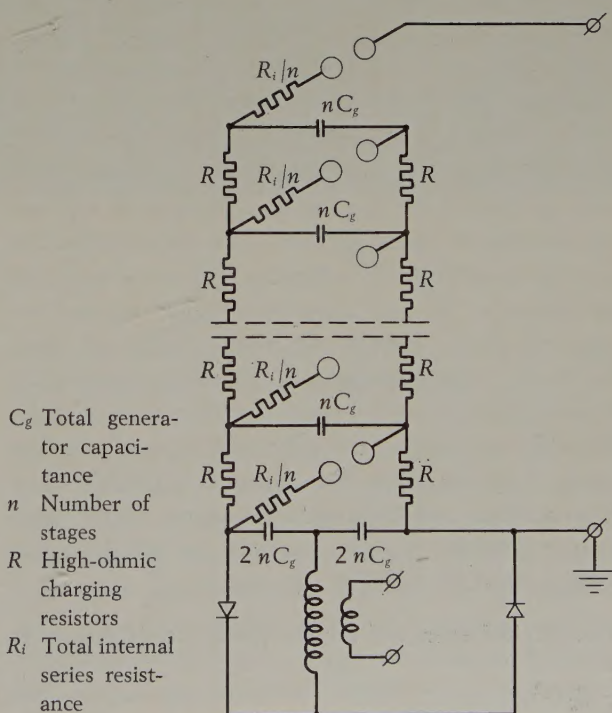


Fig. 2. Elementary diagram of voltage impulse generator. (Fr 726-1)

- C_0 Generator stray capacitance to earth
 C_g Generator capacitance
 C_T Capacitance of test object
 L_e External series-inductance
 L_i Total internal series-inductance
 L_T Inductance of test object
 R_d Voltage-divider resistance
 R_e External series-resistance
 R_g Current-limiting series-resistance to measuring sphere gap
 R_i Total internal series-resistance
 R_p External parallel-resistance

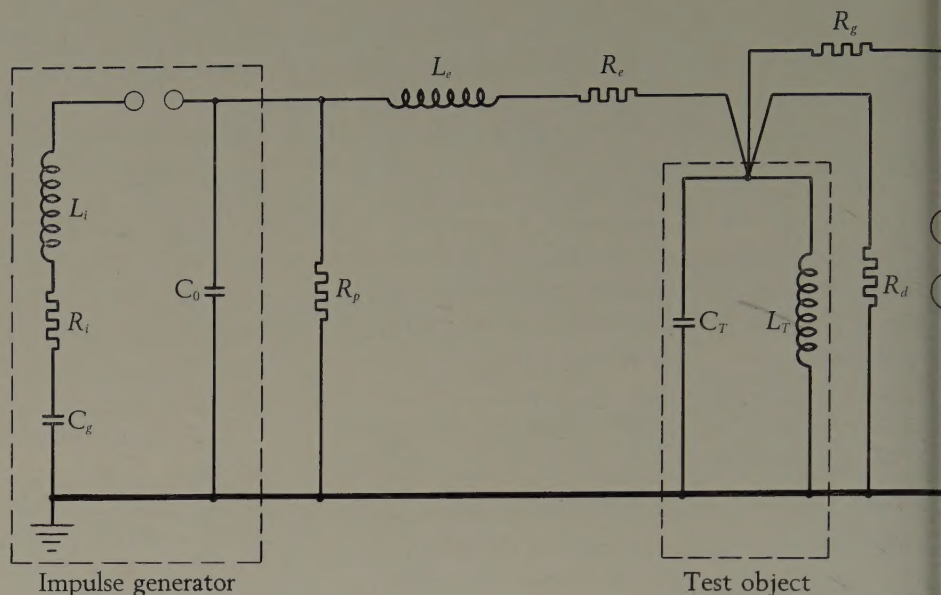


Fig. 3. Schematic impulse circuit for full impulses. (Fr 727)

The inductance of the generator and the impulse circuit must be kept as low as possible in order to prevent superimposed oscillations on the impulse. Low inductance is obtained by decreasing the dimensions of the whole circuit as much as possible and by using low-inductive resistors.

Impulse generators are characterised by the total nominal voltage, the stored energy and the number of stages.

The total nominal voltage is the highest charging voltage times the number of stages. Since the impulse generator is connected to the test object via resistors and inductances, see Fig. 3, the voltage across the test object is lower than the nominal voltage of the impulse generator. Electrical apparatus is impulse-tested with an amplitude specified in the standard specifications. It is generally necessary to check not only the withstand value but also the actual flashover voltage as well as the insulation co-ordination. In such cases even higher voltages are required of the impulse generator. Taking all these factors into consideration, it is convenient to select an impulse generator with a nominal voltage of about twice the withstand value of the test object as specified in the standard specifications. This means that 120 kV apparatus needs a 1,200 kV impulse generator, 200 kV apparatus a 2,400 kV impulse generator and 400 kV apparatus a 3,000 kV impulse generator.

The nominal energy of impulse generators is defined as

$$\frac{1}{2} C_g U^2 \quad (4)$$

where C_g denotes the generator capacitance with all stages in series and U the maximum nominal voltage.

Depending on the nature of the object for which the generator is to be used, the energy required can vary over a wide range. If the generator is to be used for testing the insulation of devices such as isolators, switches, insulator strings, etc., the energy of the generator can be quite low, i.e., about 1 kW per 100 kV nominal voltage is generally sufficient. On the other hand, if the generator is to be used for testing objects of low impedance such as transformers with high power at low voltage, the energy of the impulse generator must be higher [1]. The time to half-value for such test objects is proportional to the square root of the generator energy, see Eq. (2). When the generator energy or capacitance, is doubled, the time to half-value will thus increase by about 40 per cent.

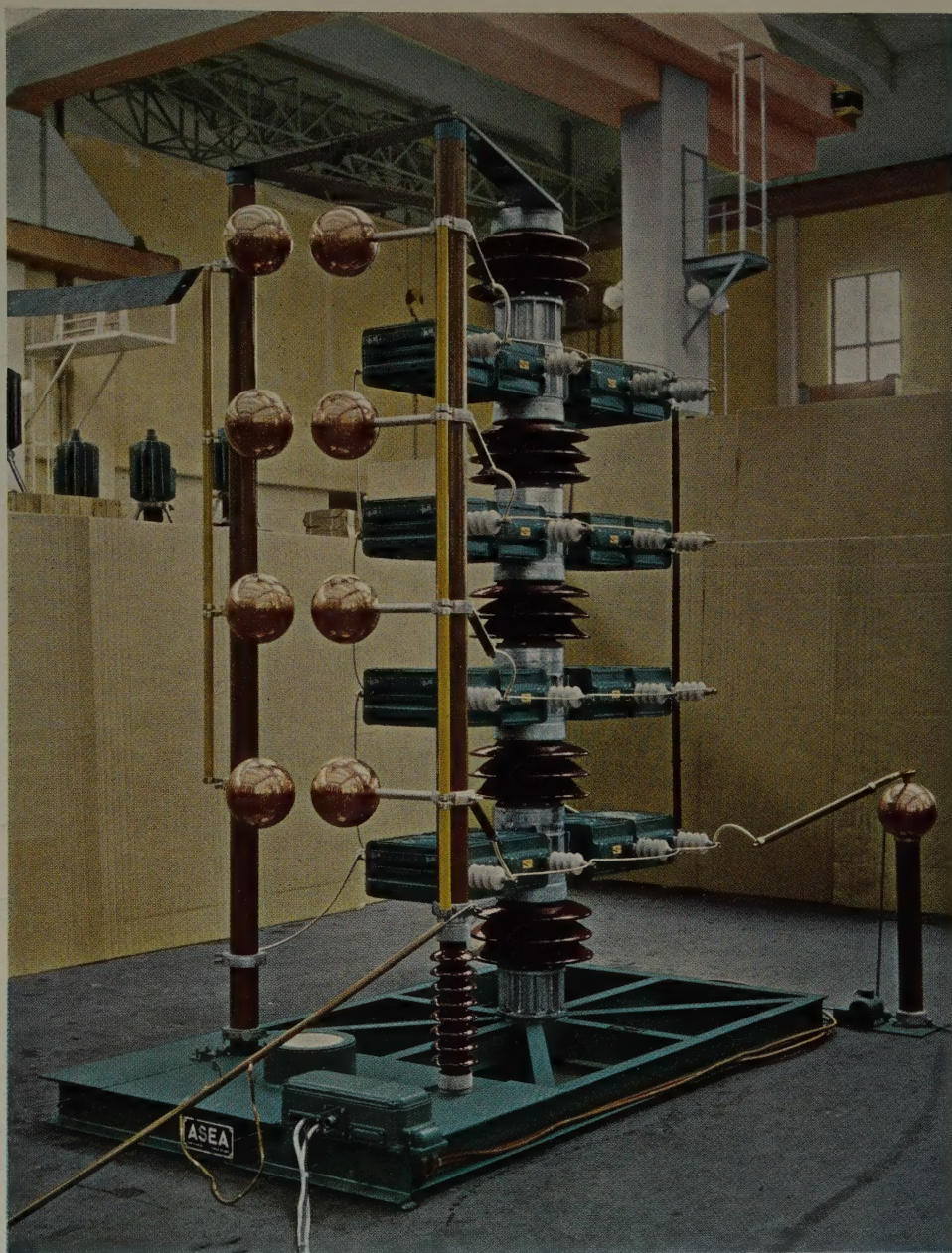
THE IMPULSE-GENERATOR EQUIPMENT

In order to meet all the different requirements in impulse testing, Asea have developed a series of flexible impulse-generator sets. The general principle has been to build an impulse-generator unit, whose different stages can be easily connected in series or parallel, thus making it possible to obtain a large number of combinations of voltage and energy to meet the requirements of different test objects. Further, the internal series resistance of the generator has been reduced to a minimum, and the desired impulse-shape is obtained by changing the external impulse circuit.

The generator as well as the external impulse circuit is assembled according to the building-block technique, that, if desired, an existing generator can be extended to a higher voltage or energy.

The different components of the Asea impulse-generator equipment are described below.

4. Four-stage impulse-generator unit for 800 kV, 1.1 kW. A higher voltage can be obtained by stacking units of this type one on top of the other. (F 1131)



Impulse generator

The impulse generator is based on four-stage units, which can be stacked one on top of the other, thus obtaining 4, 8, 12, or 16, stage generators. With 200 kV per stage this gives impulse generators having a nominal voltage ranging from 800 to 3,200 kV. In addition, each stage can be equipped with two, four or eight parallel-connected capacitors, each with a rating of 1.1 kW at 200 kV. By this means, it is possible to obtain twelve different impulse-generator ratings.

The generators are furnished with a power-distribution cubicle, a charging unit and a control desk. The whole equipment is wired up in the workshop prior to de-

livery, and all that has to be done at the site is to connect up the cubicle to the power supply.

Fig. 4 shows a four-stage impulse-generator unit with four capacitors per stage and the photograph on the cover a sixteen-stage impulse-generator unit with eight capacitors per stage. The capacitors, which are manufactured by Liljeholmens Kabelfabrik, are of standardised design with metal casing and porcelain bushings. They are mounted direct on a porcelain insulator column and are thus easy to test and replace. An impulse generator operating in a moist and polluted atmosphere and in hard daily use is liable to experience external flashovers. This insulator column can withstand such flash-

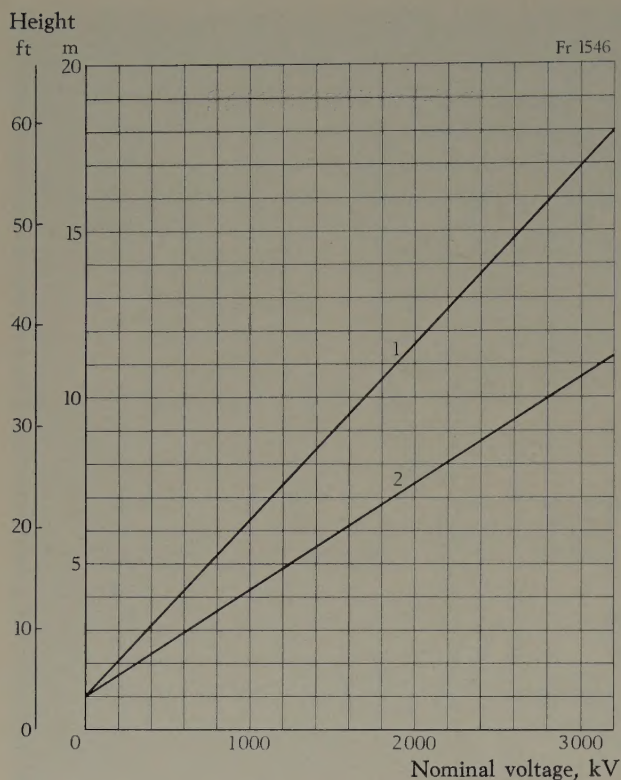


Fig. 5. The approximate ceiling height (1) and impulse-generator height (2) as a function of the nominal voltage U for the Asea impulse generators.

overs without damage. The spark gaps are mounted on separate phenolic paper tubes, as are also the vertical high-ohmic charging resistors. These resistors can easily be replaced by connection rods, enabling rapid connection in parallel or series-parallel for different voltages and test objects. Each stage has a low-ohmic series-resistor for suppressing internal oscillations.

Since the generators are built up of four-stage units, it is possible to add another unit when it is desired to increase the testing capacity. In addition, a generator supplied with a few capacitors per stage can be fitted with additional capacitors when more energy is required.

The generator is not only suitable for running tests in factories, but is also of great value to technical schools, etc., for educational purposes because of its rational design with all the connections readily visible.

When planning an impulse-generator equipment, it is important to know the height of the generator and, preferably, the total height to the ceiling that is required. Fig. 5 gives the height of the impulse generators described above as well as the approximate total height from the bottom of the generator to the ceiling as a function of the nominal voltage. It may sometimes be convenient to make a pit for the first stages of the generator to enable it to fit in a room with a limited height.

The external impulse circuit

When testing objects of low capacitance, excessive high resistance values would have to be used in order to obtain the correct front time, see Eq. (1). In such cases external "front capacitors" are used to increase the capacitance of the circuit. These capacitors can be built up to the desired impulse voltage by series-connecting 400 kV units. These units can be obtained with a rating of 400 or 2,000 pF each, depending on the desired capacitance.

When setting the correct impulse shape for different types of test object, the resistors R_e and R_p shown in Fig. 3 are mainly used, which means that their resistance value has to be varied over a wide range. The Asea generators are equipped with special woven ribbon resistors, which can easily be partly short-circuited and replaced.

The voltage-measuring equipment

The correct measurement of voltages is extremely important during impulse testing, and Asea have consequently studied this problem in great detail [2].

The amplitude of the impulse voltage is generally measured with sphere gaps. Sphere gaps fulfilling the I.E.C. specifications can be supplied by Asea for actual voltages.

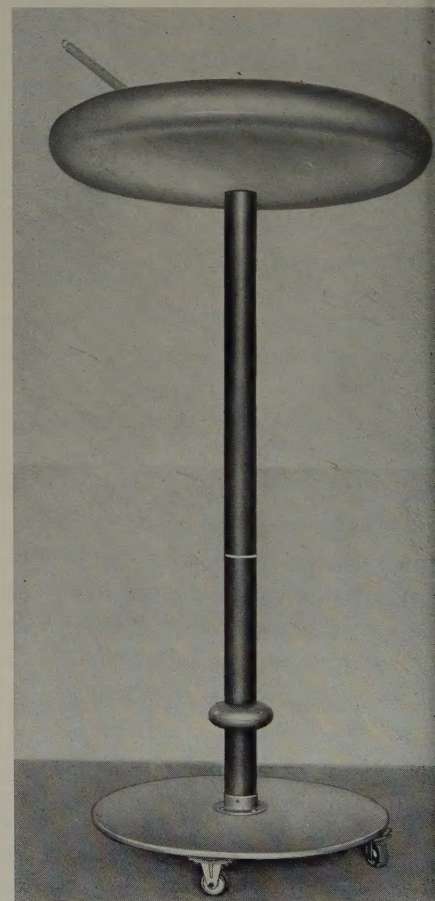


Fig. 6. Impulse voltage divider for 1,200 kV, 17,000 ohms. (57694)

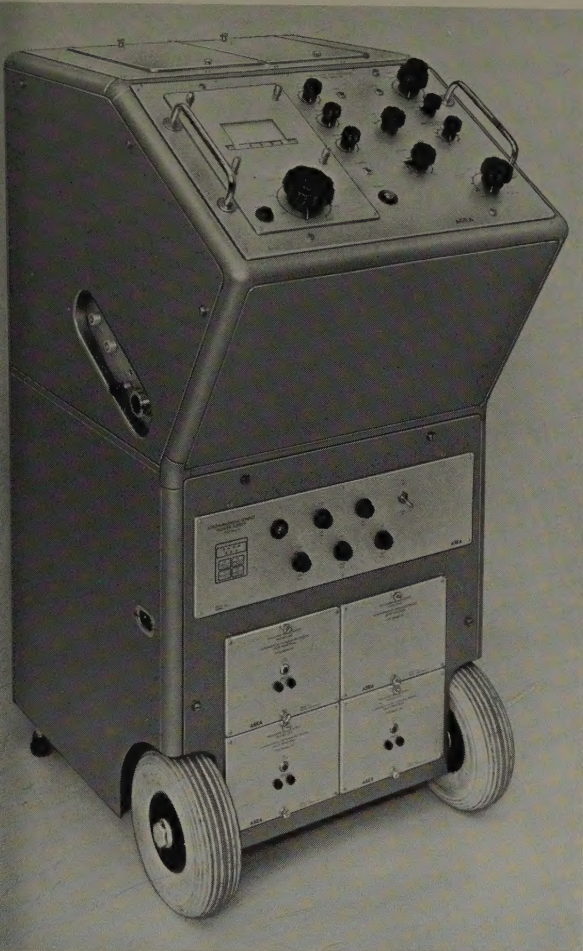


Fig. 7. High-voltage oscillograph developed by Asea for use in conjunction with impulse tests. (57695)

When measuring both the amplitude and the wave-shape, special voltage dividers and oscillographs have to be used. Asea have developed a series of impulse voltage dividers for voltages ranging from 400 kV up to about 2,000 kV with resistance values from 10,000 to 20,000 ohms. Fig. 6 shows a 1,200 kV voltage divider with a resistance of 17,000 ohms. These voltage dividers, together with the connecting leads to the test objects, coaxial cables, terminating resistors and oscillographs, have undergone special checking procedures. The whole measuring equipment has been thoroughly tested, and a certificate has been issued, giving details of its design and performance. For each test it is therefore only necessary to make a routine voltage calibration.

Asea have also developed special oscillographs for impulse testing, see Fig. 7. These oscillographs have a stabilised power supply and built-in calibration voltages. The earthing system inside the oscillograph has been made with great care in order to avoid parasitic currents which may give rise to undesired voltage drops, thus introducing measuring errors. The tripping of the oscillograph is made insensitive to the amplitude and polarity of the incoming signal. Furthermore, all oscillographs are provided with external cameras for 35-mm film and with voltage dividers having tapings in a geometrical series with a ratio of $\sqrt[3]{0.6}$ between successive tapings. This means that calibration oscillograms at 60 per cent voltage and full-amplitude oscillograms will have the same amplitude if the voltage divider is changed two steps, thus facilitating the comparison of different oscillograms. The electronic equipment used for the impulse tests is described in greater detail in [3].

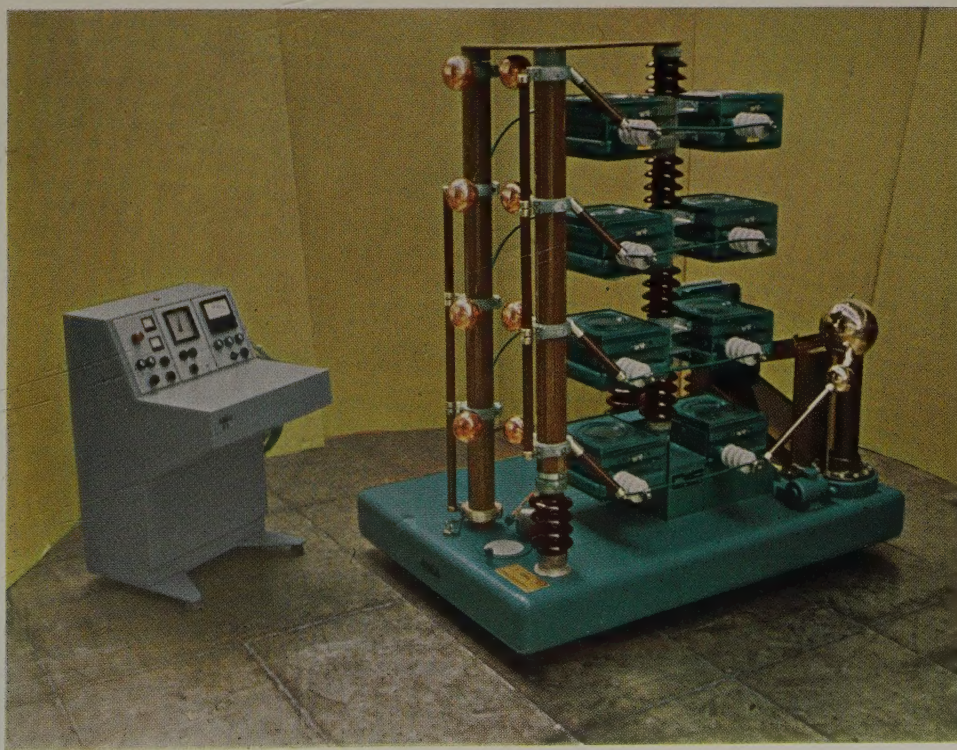


Fig. 8. Four-stage 400 kV impulse generator specially designed for the lower voltage range. (F 1132)

Table 1. Nominal energy, kW, of the Asea impulse generators.

Number of stages	Total nominal voltage kV	Nominal energy, kW, for		
		2 parallel-connected	4 capacitors per stage	8
4	800	8.8	17.6	35.2
8	1,600	17.6	35.2	70.4
12	2,400	26.4	52.8	106
16	3,200	35.2	70.4	141

Special equipment

Some of the more important components of the impulse-testing equipment have been described above, but other testing devices can also be supplied by Asea such as:

Low-inductive shunts for impulse-current measurements [4]

Special triggered sphere gaps for chopped impulses [5]

Low-voltage impulse generators up to 400 kV, see Fig
Recurrent surge generators [3]
Special neutral-point resistors [1]
Rain apparatus [6].

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MOMTAZ STEAM POWER-STATION, TEHERAN, IRAN

of Alveskog, Export Department, Västerås

U.D.C. 621.311.22
Asea Reg. 7211

The power-station described, which was supplied through AB Electro-Invest, provides a typical example of how supplies of both steam and electricity can be arranged for a factory which is to be entirely or partly independent of connection to an external grid. As there is a need for process steam in the factory, it is possible to make use of the economic advantages of the production of electric power by means of back-pressure turbines. The article also emphasises the intimate inter-connection between the steam, turbine and electrical fields and describes how regulation and co-ordination between steam and electricity have been arranged.

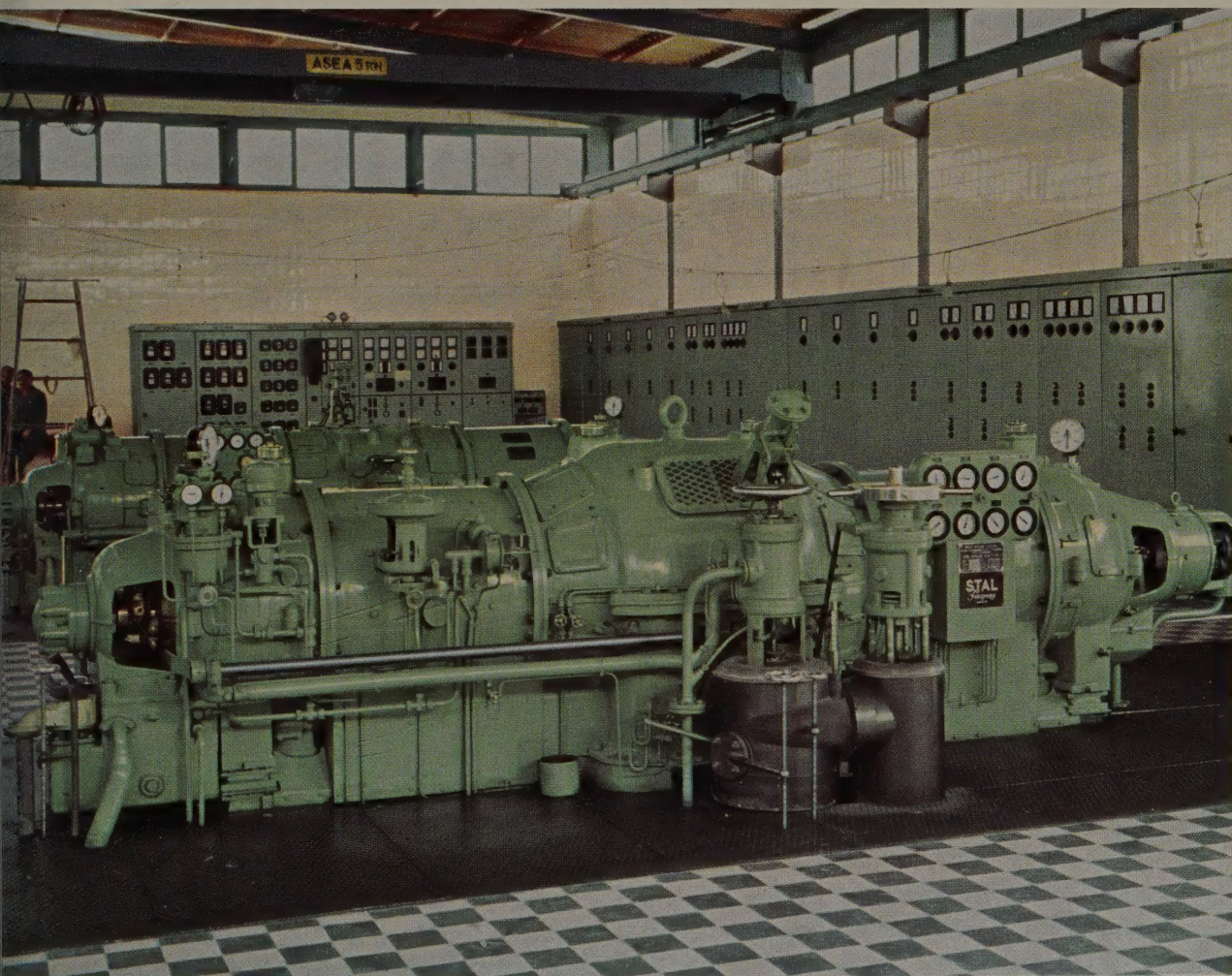
In 1958, AB Electro-Invest obtained, with Asea, AB Svenska Maskinverken and Turbin AB de Laval Ljung-
öms as sub-contractors, a contract to supply a complete steam power-station to Sherkate Sahami Risandegui va
fandegui Momtaz, Iran, usually known as Momtaz.

Fig. 1. The turbine hall with the back-pressure turbine in the foreground and the condensing turbine and the electrical control and distribution panels in the background. (F 984)

Momtaz is a newly-built textile factory, situated just south of Teheran, and is one of the largest and most modern factories in Iran, having about 40,000 spindles, about 1,000 looms and a complete department for dyeing, printing and the final processing of 80,000–100,000 metres of material per day. The complete requirements of the factory, both for steam and for electricity, are met by an older diesel power-station rated at 1,400 kW, and by the new steam power-station, supplied by AB Electro-Invest. It is equipped with a condensing turbine rated at 1,500 kW and a back-pressure turbine rated at 1,000 kW. There is also the possibility of installing another condensing turbine rated at 1,500 kW in the future. Both the older diesel power-station and the new steam power-station are now run in parallel from the latter.

THE SCOPE OF THE DELIVERY

In addition to the fact that AB Electro-Invest have acted as consultants in respect of the general arrange-



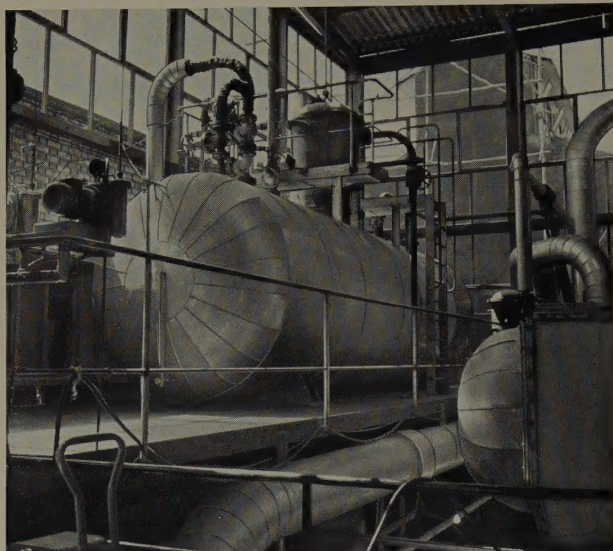


Fig. 2. The feed-water tank with the deaerator at the top. (57145)

ment of the power-station and, in conjunction with this, have checked the architectural drawings, etc., they have acted as the main contractor and co-ordinated the deliveries which, in the main, comprised all the machinery in the station. In addition to the building, including foundations, chimney and flue-gas ducts, the customer has only had to connect incoming and outgoing cables and pipes.

The erection work was supervised by Swedish erectors from the sub-contractors.

THE MAIN DATA OF THE POWER-STATION MACHINERY

The boiler plant (supplied by AB Svenska Maskinverken) comprises three oil-fired steam boilers, each with a maximum continuous load capacity of 8 tons of steam per hour at 29 atmospheres gauge (atm g), 385°C at a feed-water temperature of 105°C. The boilers are provided with rotating oil burners for heavy oil, and auxiliary equipment such as feed-water pumps, a feed-water tank and water-softening filters.

AB Svenska Maskinverken also supplied all the piping including fittings for steam, water and oil etc. in the station, as well as the thermal instrumentation.

The turbine installation (supplied by Turbin AB de Laval Ljungström) comprises two turbines of double-rotation type with three-phase generators rated at 400 V, 50 c/s, which are designed for steam at 28 atm g, 370°C at the throttle valve.

For each turbine, the economic load corresponds to the continuously permitted generator load or 1,000 kW for the back-pressure turbine and 1,500 kW for the condensing turbine at P.F.=0.8. The back-pressure turbine is designed for a normal back pressure of 3.3 atm g.

The electrical equipment (supplied by Asea) comprises 400 V distribution switchgear consisting of 24 cubicles having a total length of 17 metres, and a control and metering board having seven panels.

All the sub-distribution boards for the power requirements of the power-station itself, a d.c. system for relays and indicating circuits, automatic voltage regulators, transducer type for the turbine generators and all necessary cables in the power-station were also supplied by Asea, as was a five-ton overhead crane.

THE GENERAL LAY-OUT OF THE STATION

The general lay-out of the station can be seen from Fig. 3. The diesel power-station is in a separate building next to the steam power-station. Fig. 1 shows a view of the machine hall with the turbines and the electrical control and instrument panels in the background. To the right, a part of the long 400 V distribution switchgear can be seen.

In the present power-station building, space has been left for the future installation of a further condensing turbine with a rating of 1,500 kW, and for a boiler with a capacity of 16 tons of steam per hour.

THE ARRANGEMENT AND REGULATION OF PROCESS STEAM AND ELECTRIC POWER

A steam-flow diagram can be seen from Fig. 4. The pressure requirements of the various steam-consuming departments of the factory lie within the range 1–10 atm g. A study of the annual requirements and the distribution over various pressures showed that a back-pressure of 3.3 atm g was the most economical one and that 1,000 kW was a suitable rating for the back-pressure turbine. The requirements of steam at higher pressures than 3 atm g in the factory are covered by reduced and cooled high-pressure steam from the boilers.

From the three steam boilers, B1, B2 and B3, superheated steam is taken to the back-pressure turbine T1, the condensing turbine T2 and the reducing valve RV with the steam cooler SC, working with feed water as the cooling medium. Here, the steam at 29 atm g is reduced to about 10 atm g and is cooled to about 200°C. The outlet steam from the back-pressure turbine is taken to a 3.3 atm g steam header, from which steam is extracted, both for use in the factory and for the power-station itself.

Normally, the back-pressure turbine works with back-pressure regulation (back pressure p_2) and then automatically takes up the electric load which corresponds to the consumption of 3.3 atm g steam. The additional electric load is then distributed between the condensing turbine and the diesel power-station. If the back-pressure turbine should be working at full load and a further quantity of steam should be needed in the factory, the

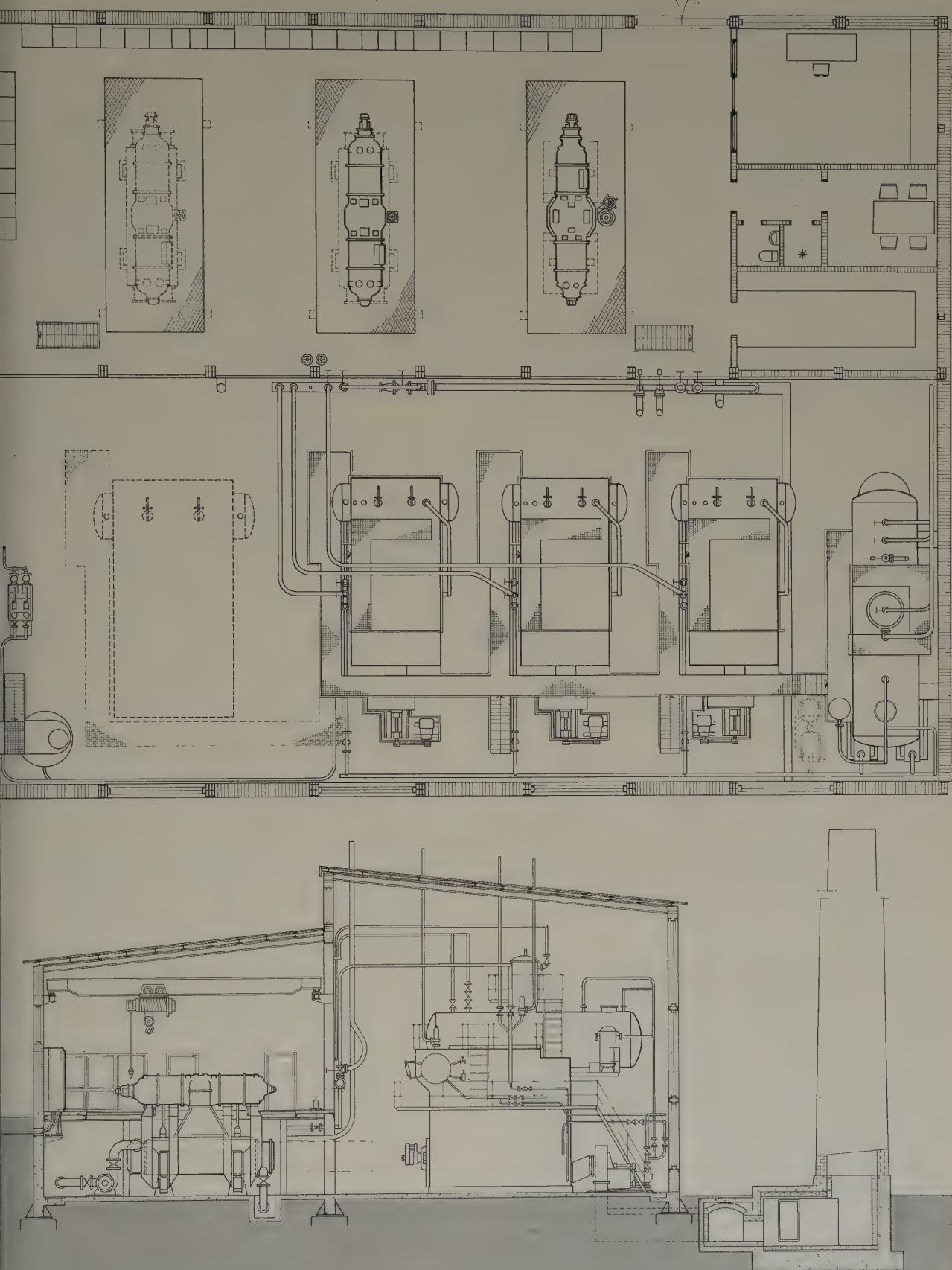


Fig. 3. Plan and section of the power-station building.

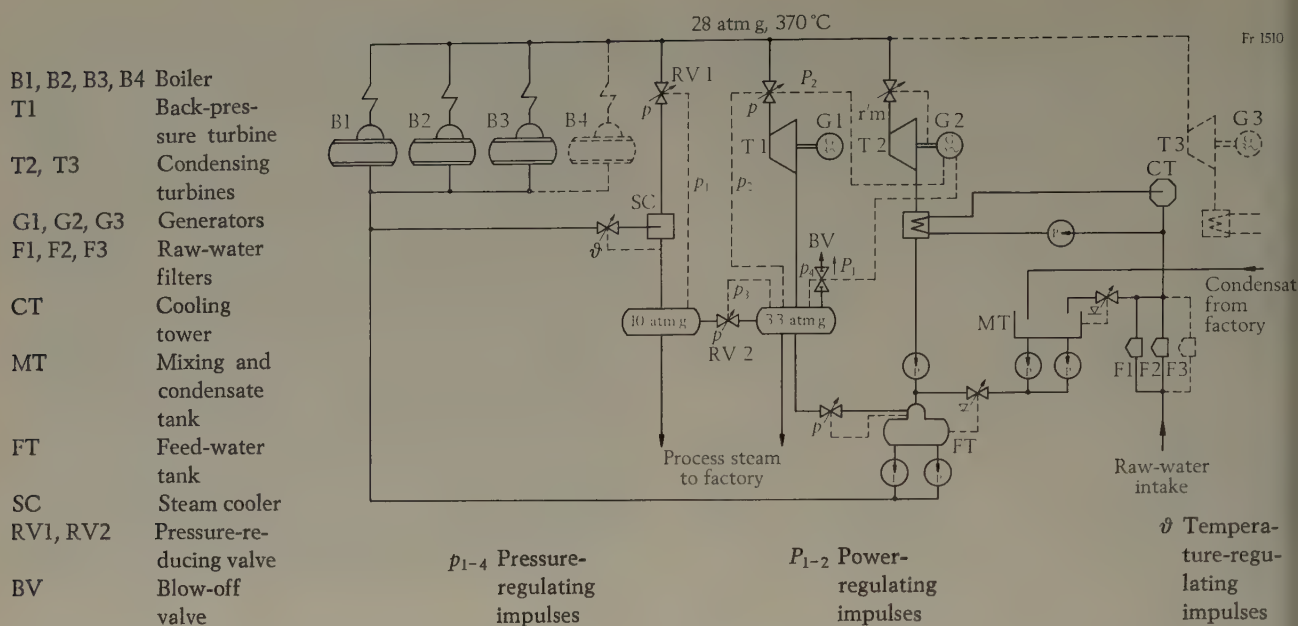
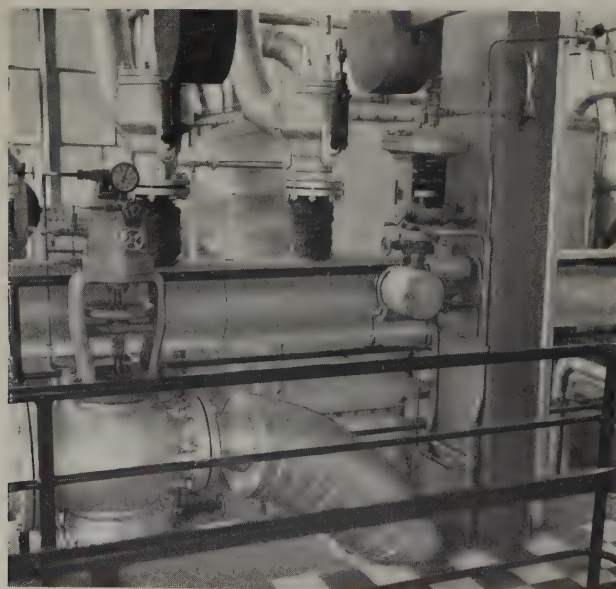


Fig. 4. Steam-flow diagram of the steam-regulating equipment.

latter can be obtained through the reduction valve RV2 from the 10 atm g steam header. RV2 is set to regulate at a pressure (p_3) which is somewhat lower than the normal back pressure (p_2).

On the 3.3 atm g steam header there is, in addition, a blow-off valve BV, which opens and lets off steam if the condensing turbine should be running at full load, so that the back-pressure turbine can temporarily take up more load than that which corresponds to the consumption of 3.3 atm g steam. The station staff then have to start a diesel generator to take up a part of the load, whereupon the back-pressure turbine returns to its original load condition. In addition, the blow-off valve serves as an extra safety valve and lets off steam

Fig. 5. Blow-off valve with servo-motor to the left and needle-valve set with pressure regulator to the right. (57146)



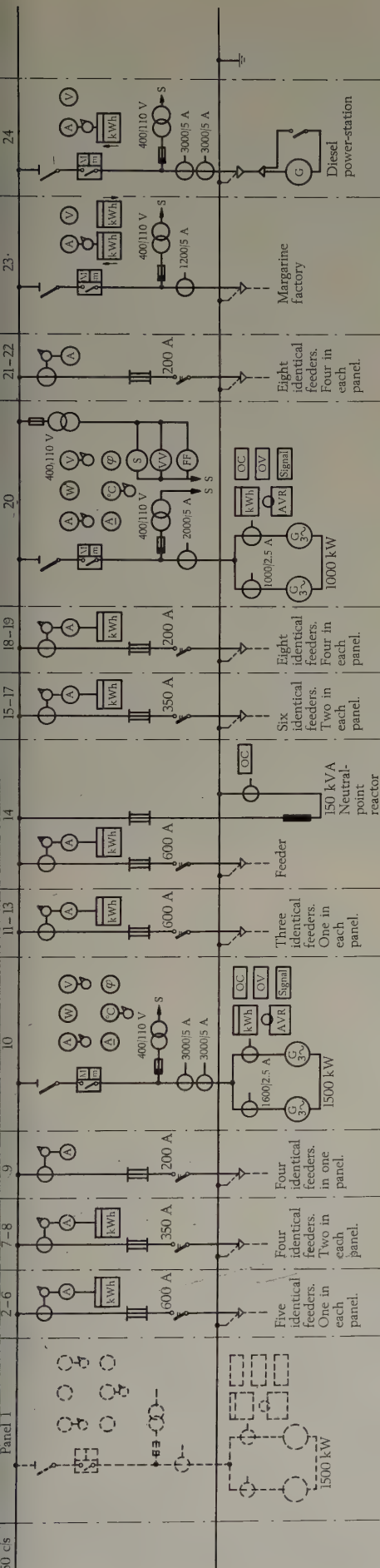
if the pressure in the 3.3 atm g steam header should become excessive (p_4).

The impulse which actuates the above-mentioned regulation sequence is obtained from a maximum-power relay connected to the condensing turbine, G2. When the output of the latter exceeds 1,400 kW (P_1), the power relay actuates, via various auxiliary relays and time-constant circuits, a needle-valve motor (to the right in Fig. 5), which then actuates a servo-motor which opens the blow-off valve BV, so that the back-pressure turbine can take up more load. The servo-motor and the blow-off valve are shown to the left in Fig. 5. The safety pressure regulator, which actuates the same servo-motor and opens the blow-off valve if the pressure in the 3.3 atm g steam header becomes excessive (p_4), can be seen above the needle-valve set to the right in Fig. 5.

A minimum-power relay is also connected to the condensing turbine G2 actuating the governor valve of the back-pressure turbine so that the load of the condensing turbine will not be lower than 70 kW (P_2).

It is possible, by means of a change-over switch on the control board, to switch over the power relays (for both maximum and minimum functioning) from the condensing turbine G2 to the busbars of the diesel power-station, or else to disconnect them entirely.

About 40 % of the steam to the factory returns in the form of condensate and is then taken via the condensate tank back to the feed-water tank and the steam boiler. In order to make up the loss of 60 % of the steam and other minor quantities of water which are lost in the power-station itself, and to supply the factory with softened water, there are two raw-water filters F1 and F2. Each filter has a capacity of 44 cu.m. per hour and they are so adequately designed that only one of them



is normally in service, the second being a stand-by. The water for the filters is obtained from two deep-bore wells situated in the factory grounds.

Because of the limited supplies of raw water, the cooling of the condenser of the condensing turbine has been arranged by means of a cooling tower. This was not included in the Electro-Invest delivery, but they arranged for technical co-ordination so that it fitted in with the turbine equipment supplied.

THE ELECTRICAL EQUIPMENT

In Fig. 6, there is a single-line diagram of the 400 V distribution system. The feeders from cubicles 21 and 22 are used for feeding the auxiliary equipment of the power-station itself, including a rectifier for charging a battery for supplying direct current to the relay and indicating circuits.

Not only can the steam power-station be run in parallel with the diesel station, but it can also be run in parallel with the diesel power plant of an adjacent margarine factory. However, arrangements have been made to enable power to be fed both to and from the latter, and therefore, double kWh-meters and reverse-power relays have been installed. No other possibility of obtaining electric power from outside has been envisaged, and the Momtaz textile factory is completely self-sufficient both with regard to steam and electricity.

The cubicles for the turbine generators, the diesel power-station and the margarine factory have been provided with motor-operated air-type circuit-breakers which are operated and synchronised from the control panel.

The outgoing feeders have been provided with air-type contactors and HRC fuses as short-circuit protection, as well as ammeters and ammeter change-over switches. In addition, all the more important outgoing feeders have been provided with kWh-meters in order to facilitate the working out of profitability and cost calculations by the management for the various departments of the factory.

All the kWh-meters, mounted in three panels, and the electrical control panels for the turbine generators, the diesel plant and the margarine factory, have been combined in a separate instrument and control panel as shown in Fig. 7.

The control panel also contains all the protective relays for the turbine generators, the power relays and other relays, all of Asea standard type. At the front of the cubicles, there are signal stations with signal relays for fault indication in the electrical installation, and in the cooling and lubricating systems of the turbines. In the case of a fault indication, an alarm signal is also given by bells in the turbine hall.

Fig. 6. Single-line diagram for the power-station. (Fr 1511)

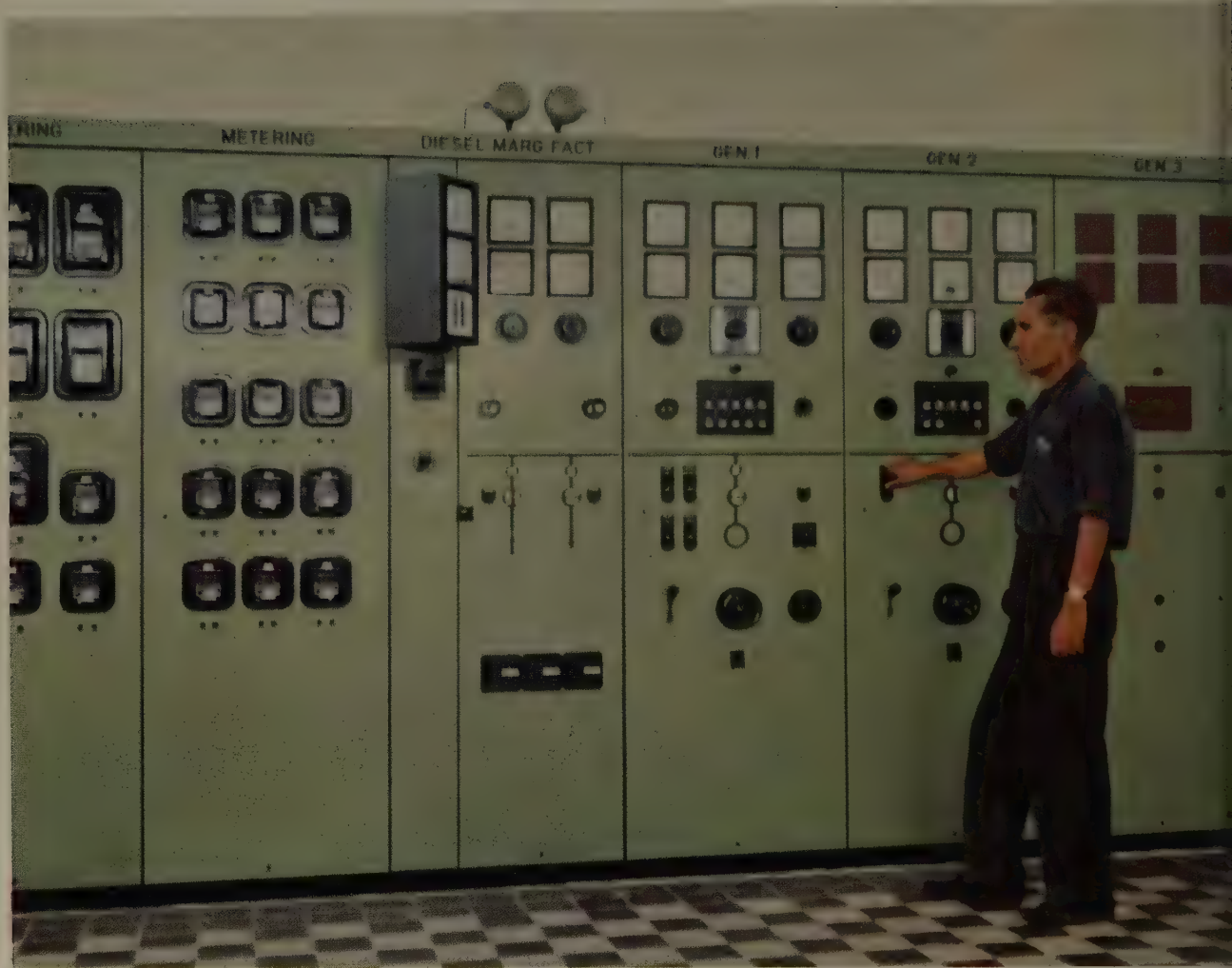


Fig. 7. The control and instrument panel with a vacant panel to the right for a future turbine, and two of the three panels with kWh-meters to the left. (F 985)

The electrical system is directly earthed, and to prevent currents circulating between the generators, and to make possible stable parallel running under all service conditions, a Z-connected neutral-point reactor having a rating of 150 kVA has been connected between the three phases and the neutral. The neutral-point reactor is provided with over-current protection which trips the main circuit-breakers of the station in the event of over-currents, and there are fuses as short-circuit protection.

CONCLUSION

The steam power-station described above is a typical example of how supplies of steam and electric power can be arranged in the case of a textile factory which is to be entirely or partly independent of any external grid. Several other industries, for example, sugar refineries, paper mills and various food industries, have similar requirements for both steam and electric power, and the same or similar types of power-station with

both back-pressure and condensing turbines suited to other steam and electric power data, can then be used. The economic advantages of electric power production by means of back-pressure turbines, when there is a need for low-pressure steam, are well known.

It is also apparent from the description that it is difficult to draw any definite limits between the steam turbine, and electrical, fields, but that all three are technically linked with each other and must be co-ordinated to obtain the best service results.

Even if the factory management has personnel who are qualified in steam and electrical engineering, it is still often the most rational and economic solution to have over the entire contract for the delivery of a steam power-station to a co-ordinating authority such as AB Electro-Invest. They can then also serve as consultants and work out the complete technical specifications for the sub-contractors.

As the name implies, AB Electro-Invest also have the possibility of offering extended payment terms and can consequently assist in solving both the technical and economic questions connected with complete installation of this nature.

SUBMERGED BULB UNIT IN SKOGSFORSEN POWER-STATION

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U.D.C. 621.313.322-821.2
Asea Reg. 4421, 7215

The advantages of the submerged bulb unit in terms of capital cost and efficiency will in many cases make it a particularly suitable choice of power unit for small hydroelectric power-stations. A typical example of such an installation is the Skogsforsen station, owned by the Yngeredsfors Power Company, for which a submerged bulb unit has been designed and built by Asea and Karlstads Mekaniska Werkstad (KMW). Special factors in the design of the turbine and generator were the particular operating conditions which apply to this power unit.

The design of machines and civil-engineering works for hydro-electric power plant has not undergone any radical changes since the general acceptance, nearly fifty years ago, of the main types of waterwheel unit known as Pelton, Francis and Kaplan turbines, each with its own range of application. Development in this field has instead been directed towards improvements in the design and construction of certain turbine and generator components, higher efficiency and greater reliability, coupled with a steady trend towards larger power units.

Nevertheless, the interest in harnessing small water-power resources suitably located with regard to power-production requirements has not abated. Power plants in this category may often, with advantage, be designed for short periods of power production, used for meeting peak-load demands and to some extent for supplying priority power in the event of power failures on the grid.

Fig. 1. Skogsforsen power-station. In the foreground, the tail race of the submerged bulb unit, on the left the temporary entry crane used for erection. The old power house and dam are seen in the background, also the intake for the new power unit. (56733)



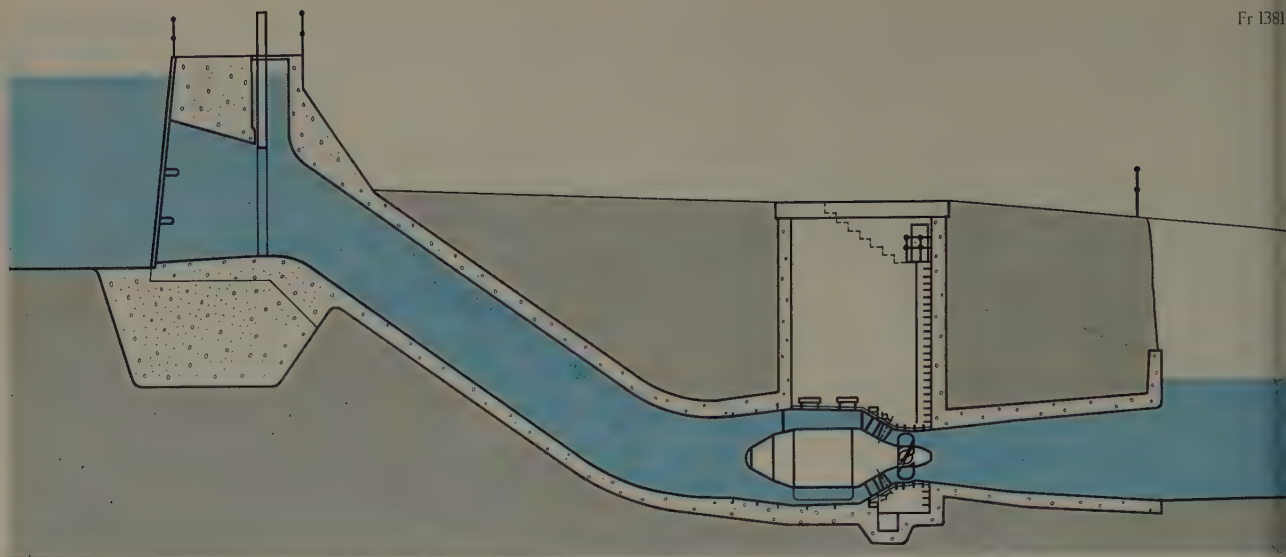


Fig. 2. Section through the hydraulic flow path.

In order to keep operating costs low, small power plants of this kind are usually designed for fully automatic operation and remote control. The greater part of the capital outlay in building a hydro-electric power plant is absorbed by the building construction work. A radical simplification of the civil-engineering work that the hydraulic circuit and the power house entail has been made possible by the advent of the submerged bulb unit. The idea in itself is not new, but has only recently been put into practice during the past decades in a number of installations in Germany and France. An example of this is the present scheme to canalise the river Moselle which flows through France, Luxemburg and Germany, where submerged bulb units are being installed beside the sluices. Eventually these power units will provide a total output of about 200 MW. Another example is the large tidal-power project at Rance in Brittany, planned by Électricité de France, where 24 units are to generate a total output of 240 MW. It was in fact owing to the French tidal-power project that the KMW company became interested in submerged bulb units through their French licencees who, having been consulted while the project was still in the planning stage, contributed towards its realisation by carrying out numerous tests and studies. Much of this work was done by means of model turbines at the KMW laboratory at Kristinehamn, Sweden.

Experience gained in the course of this work later proved valuable when designing the bulb unit for the Skogsforsen power-station in southwestern Sweden. In this case, the power company concerned was faced with the task of finding the simplest and least costly method of installing an additional power unit in an existing power-station (Fig. 1) with the object of increasing the

degree of water-power utilisation to the level of the other stations on the river Ätran. The investigation covered a conventional power unit driven by a Kaplan turbine, similar to the existing plant, a much simplified Francis-type turbine with a horizontal shaft and, finally, a submerged bulb unit. The last alternative was found to be the most advantageous both as regards capital cost and efficiency.

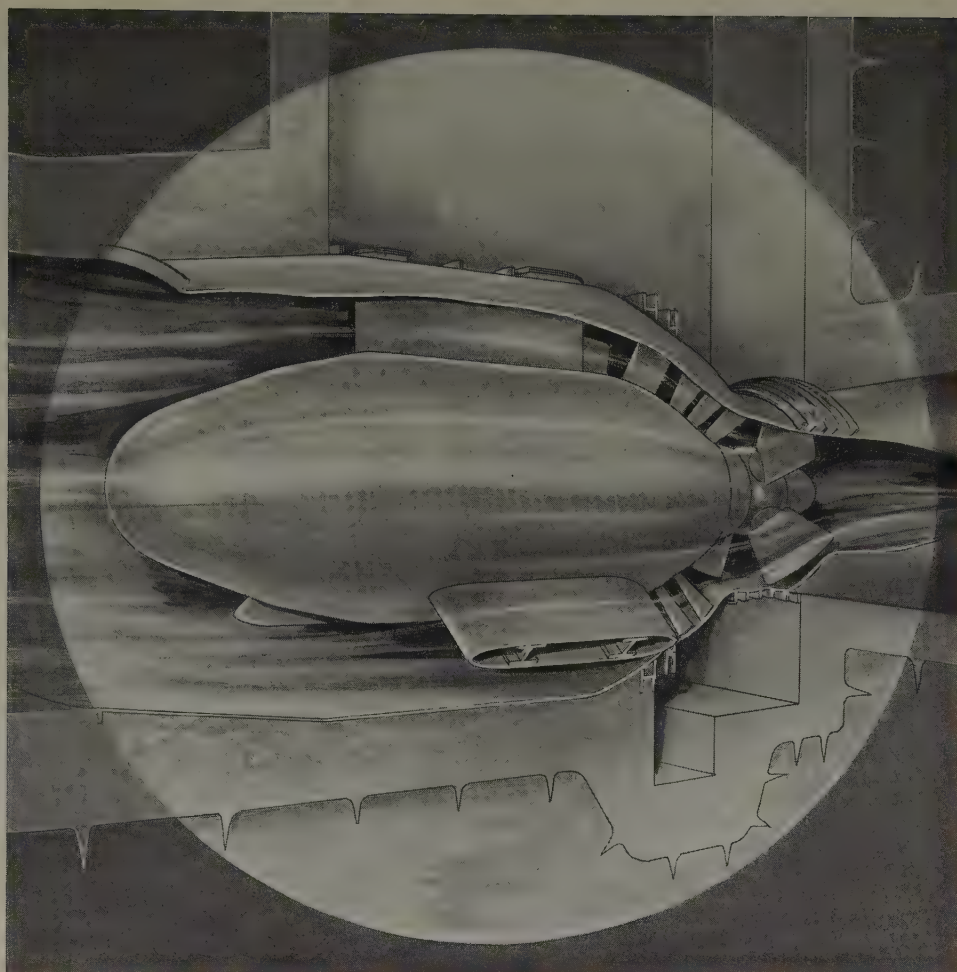
As will be seen from Figs. 2 and 4, the bulb-shaped shell carrying the generator and turbine is mounted concentrically in a tubular shell which forms a conduit for the water. The turbine has conical guide-vanes and a horizontal shaft runner, an arrangement giving a virtually axial flow through the turbine and resulting in an appreciable improvement in efficiency compared with that of a power unit of conventional design.

The turbine has a rated output of 3,600 kW at an effective head of 14 m (46 ft). A cross-section through the power unit showing the arrangement in some detail is given in Fig. 4.

The turbine section includes a stay-ring which serves the dual purpose of directing the water flow and supporting the turbine. The generator casing is carried on two stream-lined legs which rest against the tubular conduit shell set in the concrete. At the lowest point of the casing there is a drain outlet with an alarm device which operates in the event of water leaking into the casing.

Oil is supplied to the bearing and servo-motor actuating the runner blades, which is located inside the flange joining the generator and turbine shafts, via the combined guide bearing and oil-pressure housing. The feedback movement from the servo-motor is transmitted by a rod passing through the lower radial member of the stay-ring. The adjustable guide vanes are connected

Fig. 3. Sketch of the submerged bulb unit. (Z 12038)



links to a control ring which is actuated by a servomotor located adjacent to the runner chamber. In order to guard against low-speed rotation which might otherwise be caused by water leaking past the closed guide vanes, a strap brake is fitted around the shaft flange.

Oil pressure for actuating the guide-vane ring, runner vanes, brake, etc., is supplied by a pump set comprising a pump, pressure vessel and oil tank. The two control valves for varying the runner-vane pitch are also housed in the pump set. A carbon gland box located between the runner and the turbine bearing prevents any leakage of water along the shaft.

The generator is a horizontal synchronous machine with a rated output of 4,250 kVA at P.F.=0.8, speed 250 rpm, voltage 6,600 V, star-connected. This machine differs from the conventional design of horizontal generator in several respects. It has somewhat unusual proportions, the external diameter being restricted by the requirement that the dimensions of the annular flow path should not greatly exceed the diameter of the runner. The manner of cooling the machine is also uncommon, the heat losses being partly conducted away through the stator casing to the water, partly by cooling

air circulating axially through the machine and giving up its heat to the up-stream cone, which has been specially designed to act as a heat exchanger. In order to facilitate the first-mentioned direct cooling action the stator casing has been shrunk on to the stator core package. Prior to shrinking on, the outside diameter of the core package was turned and cadmium-plated so as to ensure good thermal contact and to reduce the danger of corrosion. Before inserting the stator windings, the core was dipped in varnish to protect the bright metal surfaces. Circulation of the cooling air is maintained by fan blades fixed to the rotor and by a separately driven fan mounted in the nose of the up-stream cone. Cold air flows through the bearing frame and after passing through the rotor spider is deflected 180° by a partition on the down-stream side of the rotor. The return flow path is formed by the gaps between the poles, the air gap, and finally the heat exchanger. Thus the air circulates only through the generator section, which simplifies the task of keeping the generator dry. When the machine is stationary, the electrically driven fan keeps the air in circulation and maintains it at a slightly elevated temperature, thereby counteracting any tendency to condensation.

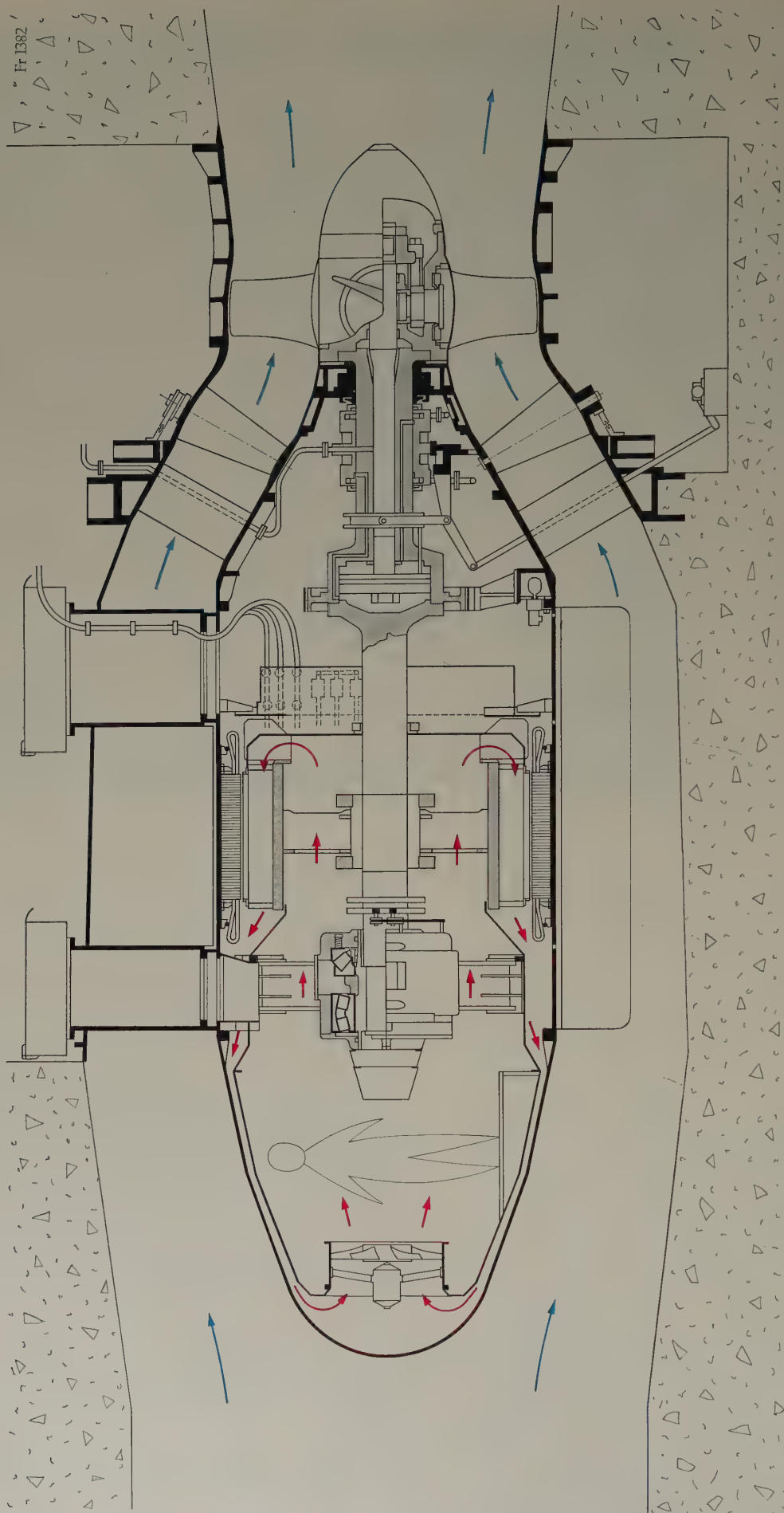


Fig. 4. Cross-section through the power unit. Turbine rating 4,875 h.p. at a head of 14 m (46 ft) and 250 r/m. The generator is rated at 4,250 kVA at P.F. = 0.8, 6.6 kV, 50 c/s. The outer diameter is 2.4 m (7 ft 10 in.) and the overall length 8.7 m (28 ft 6 in.)



Fig. 5. View down shaft showing upper part of conduit shell, runner chamber and control gear and the hydraulic equipment. (56734)

The up-stream end of the generator shaft is supported by axial and radial SKF roller bearings in a common bearing housing, the axial bearing being designed to withstand the hydraulic thrust of 60 tons exerted by the runner. These bearings run in oil, and in order to prevent oil from leaking out of the housing a small fan is fitted which maintains reduced air pressure inside the bearing housing. It will be seen from the illustrations that this is the only generator bearing provided, the other end of the generator shaft being rigidly flanged to the turbine shaft.

Access to the interior of the unit is through two vertical shafts, fore and aft of the generator, where there is sufficient space to accommodate several persons for the purpose of inspection and maintenance of the bearing, oil-rings, oil-pressure housing, brake, servo-mechanism, etc. An overspeed governor of mechanical design and tachometer generator for low-speed indication are mounted on the bearing housing.

The stator winding is of conventional diamond-coil pattern. Class B insulation is used both for the stator and rotor windings. Because of the effective cooling, winding temperatures are kept well below the level stipulated in standard specifications.

Plastic-insulated 6 kV cables laid in the down-stream access shaft carry the generator current to a 50 kV transformer in the outdoor switchyard. No neutral conductor is included in the cables, the neutral point of the stator being formed in the generator by Araldite-insulated current transformers. Field current is supplied by a separate rotary-converter unit located in the existing power house, which also contains the voltage regulator and all other control equipment. The whole power unit is fully automatic and is operated and supervised by remote control from the power company's load-dispatch station located about 100 km (60 miles) away at Krokslätt, south of Gothenburg. (The other hydro-electric power plants belonging to the company are also controlled from the station at Krokslätt. All the automatic operating and remote-control equipment was supplied by Asea.)

The unit is started up by opening the guide vanes to a predetermined setting. As the turbine revolutions approach the normal running speed, the field circuit is closed and the speed is regulated in conformity with the network frequency by means of impulses to an electric motor in the turbine control gear. When the generator has been synchronised with the network, the turbine setting and excitation may be adjusted to give the desired active and reactive power. No speed governor is fitted as the unit is not intended to operate as an inde-

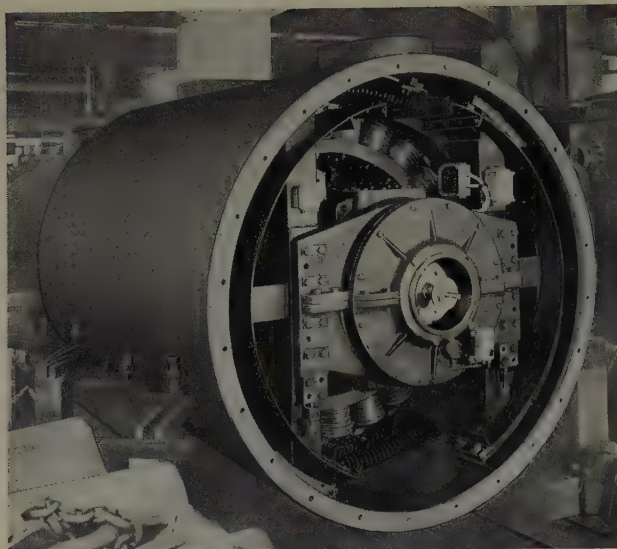


Fig. 6. The generator on test in the Asea works. (54704)

pendent source of power. However, in the event of an interruption in the linkage between the power company's stations and the national grid resulting in a drop in frequency below 49.0 c/s, a relay is provided which

will cause the guide vanes to open fully. On the other hand, a rise in speed of more than 10 per cent above normal will result in the machine's being tripped by a mechanical overspeed switch. Unless tripping has been caused by some electrical or mechanical fault, the unit may be started up again immediately by remote control. Should the tendency to overspeed persist, the intake gate is automatically lowered.

The unit is equipped with the usual automatic operating protection against internal and external short circuits and earth faults, excessive winding and bearing temperatures, as well as equipment for indicating various minor faults.

The turbine and generator sections were tested independently at the maker's works, KMW and Asea respectively, prior to delivery and the two sections were joined together for the first time at the site when the assembled power unit was lowered into position.

Except for some minor trimming work, the Skogsfors submerged bulb unit has been in regular service since July, 1960, during which time it has fully justified expectations.

A DANISH HEAVY-PLATE MILL

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U.D.C. 621.771.232.4
621.313.2.077.3
Asea Reg. 817

The article presents a brief description of the electrical equipment in the plate mill, which consists of two d.c. motors each rated at 3,000 kW with a maximum torque of 180 ton-metres, an Ilgner converter with a 5,500 kW driving motor and four generators, regulating equipment, d.c. motors for the front-and-back roller tables and the screwdown, control equipment, and pressductors for measuring the roll force.

Since June 1960, a heavy-plate mill has been in operation at the Frederiksværk steelworks of Det Danske Staalvalseværk A/S. The plate mill consists of a four-high rolling mill with a work-roll diameter of 900 mm and a work-roll length of 3,300 mm. Asea supplied the main machinery and most of the auxiliary machinery, as well as the high-voltage and low-voltage distribution equipment for this rolling mill.

The rolling mill itself is driven by two reversing d.c. motors with laminated stators, each rated at 3,000 kW, 0–50 r/m with shunt regulation to 100 r/m and a maximum torque of 180 ton-metres. As will be seen from Figs. 1 and 2, the motors are arranged in twin drive, that is to say, they are connected to their work rolls by means of spindles. In order to enable the motors to take up the axial forces which arise in normal service from the rolling mill and the connecting spindles, and, similarly, the large axial forces which can arise if a roll spindle should break, each motor has been provided with a heavy-duty thrust bearing.

The motors are supplied from an Ilgner converter with four generators, two for each motor. It can be seen along with the main motors and auxiliary converter in Fig. 2. There is space in the converter set for y

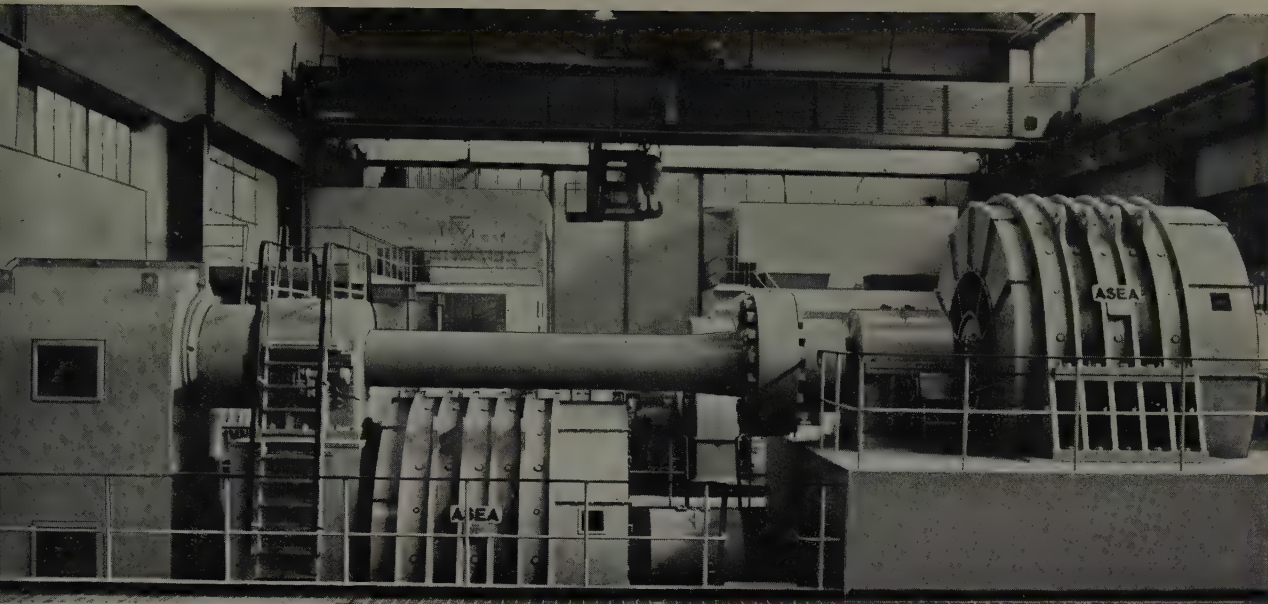


Fig. 1. The 3,000 kW driving motors are connected to the work rolls by means of spindles. (56145)

other generator for an edger stand which may be installed in the future. The converter has an eight-pole driving motor rated at 5,500 kW, 6 kV, and a flywheel with a moment of inertia of 49,000 kgm² and a weight of 29 tons.

There is common voltage-regulation equipment for the motors. In addition, there is equipment which regulates the desired speed ratio between the two motors, this being quite simply set by means of a knob in the control room. Thus, the two work rolls do not need to have the same diameter. Above the base speed, that is, say, between 50 and 100 r/m, the motors are shunted, reducing their field current.

The rolling-mill motors are provided with current-limit regulation, which means that a heavier load than the maximum one permitted cannot be imposed on the motors. If a load peak of this nature should occur within the shunt range, the motor field is reinforced and consequently the torque increases at the same time as the speed drops, if necessary, down to the base speed. If the load should still be too great, the voltage is then reduced, if necessary down to standstill. Thus, there is no tripping of the over-current circuit-breakers with the consequent interruption to service. For all regulation of the main machinery, use is made of transducer amplifiers and generator exciters.

For driving the front-and-back roller tables and the screwdown, use is made of d.c. motors (type LRC) specially designed for heavy duty. These motors correspond with the AISE standard as far as the essential electrical and mechanical data are concerned (Fig. 3).

The motors are fed from generators in converters driven by synchronous motors.

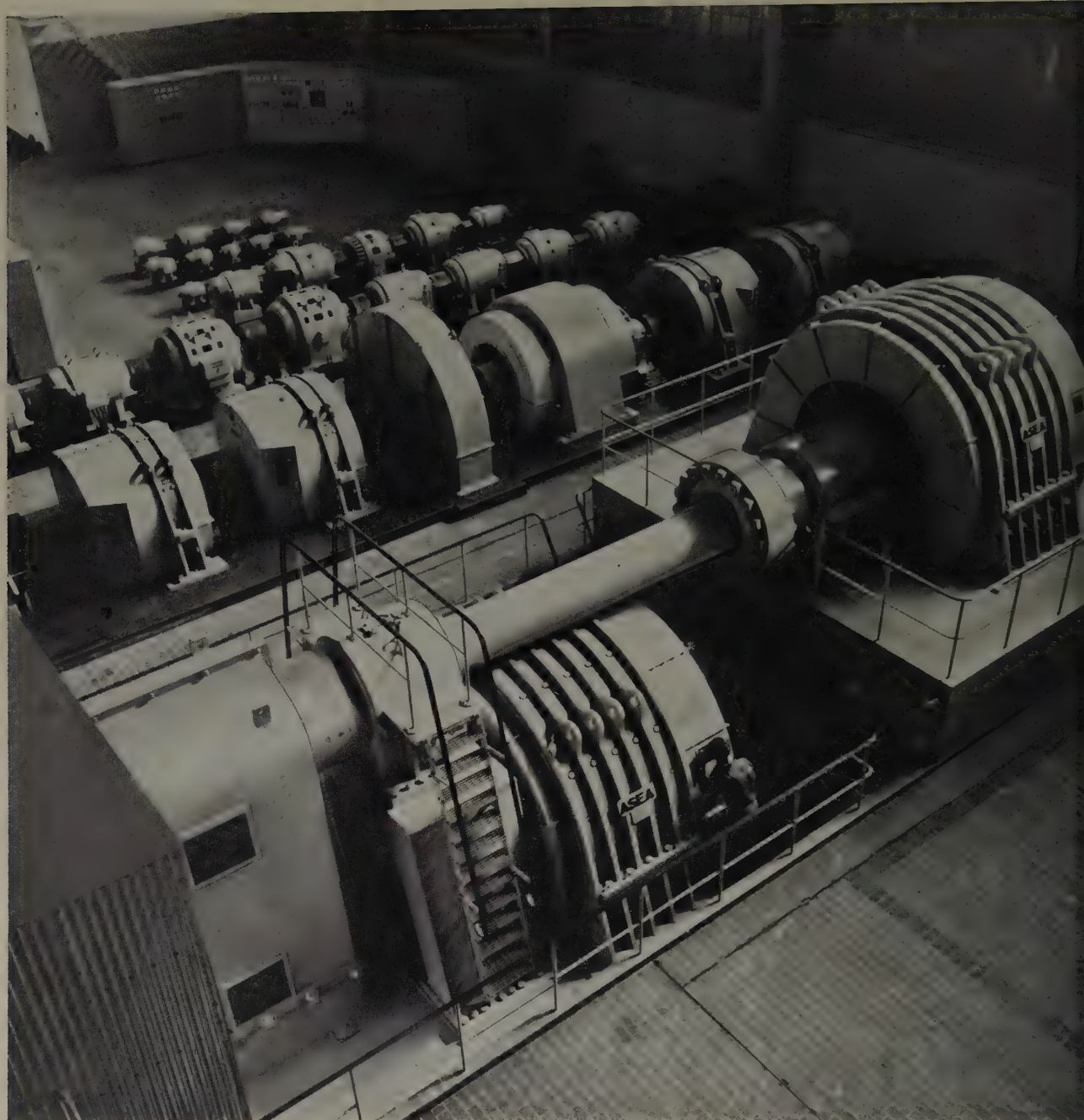
The voltage to the auxiliary machines is regulated with the aid of transducer amplifiers and generator exciters. The motors have regulable constant acceleration and retardation between the various speed positions irrespective of how the control lever is operated.

In addition to the above-mentioned acceleration control, the screwdown machinery is provided with current-limit regulation in order to prevent tripping if it should happen that the rolls are screwed down against an ingot.

The plate mill and the auxiliary machinery are operated from a cabin at the side of the mill. The mill and the roller tables are operated by means of the common controller. Further, the roller tables can be run separately with the aid of another controller.

All the regulating equipment, protective relays, operating equipment etc. are grouped in one control panel, see Fig. 4.

A pressductor [see Asea Journal 32(1959):9, pp. 115-123] for a nominal load of 1,600 tons is inserted between each screw and the bearing of the upper backing roll in order to measure the roll force. There are both indicating and registering instruments for the roll force. The latter registers not only the roll force, but also the motor currents and speed, thus making it easy to follow a rolling operation and to check the loading on the driving machinery and the rolls. An additional refinement which can be mentioned is that a sensitive relay, which drops out at very low roll forces, is connected to the pressductor equipment. The relay has been used,



amongst other purposes, for preventing starting of the screwdown machinery when an ingot is in the rolling mill. Further, the relay can be used for turning up the first end of the rolled plate. This can be arranged by rotating the lower roll somewhat faster than the upper roll when the mill is running under no-load. This extra speed is then dispensed with as soon as the roll force indicates that there is an plate in the mill.

The rolling mill is provided with three-phase voltage at 6 kV, 50 c/s, via metal-clad switchgear with 13 cubicles. The circuit-breakers in the cubicles are oil-minimum circuit-breakers of type HKN 10/1000 with a rated current of 1,000 A and a breaking capacity of 300 MVA at 10 kV and 200 MVA at 6 kV.

Fig. 2. The driving motors, the Ilgner converter, auxiliary machinery and control panel at Det Danske Staalvalseværk A/S. (56146)

The auxiliary a.c. machinery and other low-voltage equipment is fed from two 400 V distribution switchgear units each having 14 cubicles. The two distribution switchgear units have been set up back to back with suitable distance between them, and in this space the secondary resistors and capacitors for power-factor correction have been located. Doors have been placed at both ends so that the gangway between the distribution switchgear units has become a separate space which can be locked. All the contactors for heavy duty are directly operated.

the circuit-breakers in the main d.c. circuits for the main machines and auxiliary machines are situated in the basement beneath the machine room. The circuit-breakers for the main machinery have been set up separately beneath the main converter in the best way with reference to the locating of the busbars. The measuring devices for current and voltage mounted on open frames, circuit-breakers, and measuring devices for the auxiliary machinery are also located here. The entire area in the basement with the non-enclosed equipment has been fenced off and locked.

The main motors and the main converter are cooled with the aid of a closed ventilation system in which the air flows from the machine room down through the machines to the basement, whereupon it passes through a water cooler, main fans of centrifugal type, and back to the machine room. In the foundations of the main motors there are propeller fans which serve the purpose of levelling out the higher pressure drop in these machines. Booster air is taken in from outside through a filter, thus ensuring that the air in the machine room is at a pressure slightly above atmospheric. The booster air is also sufficient for ventilating the auxiliary machines in the rolling mill. The air for these is taken from the machine room and blown out through the various motors with the aid of special booster fans.

3. The d.c. motors for driving the front-and-back roller tables and the screwdown are specially designed for heavy duty. (52949)

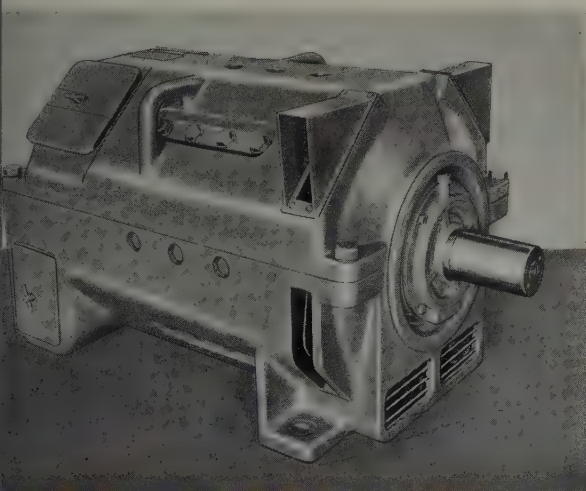


Fig. 4. The control board with regulating equipment, protective relays, operating equipment, etc. In the foreground, the excitation converters. (56147)

The keeping of spare parts for the new rolling mill has been simplified thanks to the fact that, a year previously, Det Danske Staalvalseværk A/S had installed a slabbing mill with the same main generators as in the new heavy-plate mill. Therefore, a spare rotor can be kept in reserve for no less than six exactly similar generators.

The two converters for the auxiliary machinery, which are driven by synchronous motors, are so arranged that they can be connected together and driven by one motor, and a jack shaft can be inserted instead of the faulty motor. There is a spare generator in the one set, and since all the generators have exactly the same dimensions, even though their electrical data are somewhat different, the spare generator can be moved and incorporated at any point.

As a spare for the exciters for the main machinery, there is a special set for the driving motor and exciter designed so that it is suitable both for the generators and the motors in the heavy-plate mill and in the above-mentioned slabbing mill. There are portable spare machines for the smaller exciters.

A LADLE CRANE

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U.D.C. 621.874
621.746
Asea Reg. 6342

At the end of 1959, Asea supplied an 80/16 ton ladle crane of the most up-to-date design to SKF for use at Hofors Bruk. The crane is primarily intended for transporting molten pig iron in the new desulphurisation plant at the steelworks.

The main data of the crane are as follows:

Span	16 m (52 ft)
Lifting height	
The 80-ton hook	12 m (39 ft)
The 16-ton hook	12.5 m (41 ft)
Hoisting speed	
The 80-ton hook	0.08 m/s (0.26 ft/s)
The 16-ton hook	0.125 m/s (0.41 ft/s)
Crab travel	0.5 m/s (1.6 ft/s)
Crane travel	1 m/s (3.3 ft/s)
Maximum wheel pressure	31 tons
Wheel base	1.3 - 4.4 - 1.3 m (4.3-14.4-4.3 ft)

Because of the great demands made on reliability in service, and durability, a crane with a high standard of workmanship was selected. Thus, the bridge of the

ladle crane is of box-girder design. All the gears are provided with helical gear wheels running in oil. The hoisting machinery is welded throughout and all the rotating shafts are provided with roller bearings. The wheels have no flanges and the track is made of high class steel. Horizontally mounted guide rollers take up any lateral forces which may arise during crane travel.

The comfort of the crane driver has not been neglected. Since the premises are very hot and dusty, the cabin is of enclosed design and is, in addition, provided with an air-conditioning set of entirely new type.

The main hoisting machinery is provided with an electrical crane-weighing device. Two pressureducers are mounted at the sides of the equalising pulley so that they measure the weight of the load. The metering values are transferred electrically to a pointer instrument graduated in tons and located in the driver's cabin.

The hoisting machinery of the crane can be operated at crawling speed. Low speed is obtained by connecting the motor to a low-frequency alternating voltage which is generated by a low-frequency converter mounted on the crane bridge.

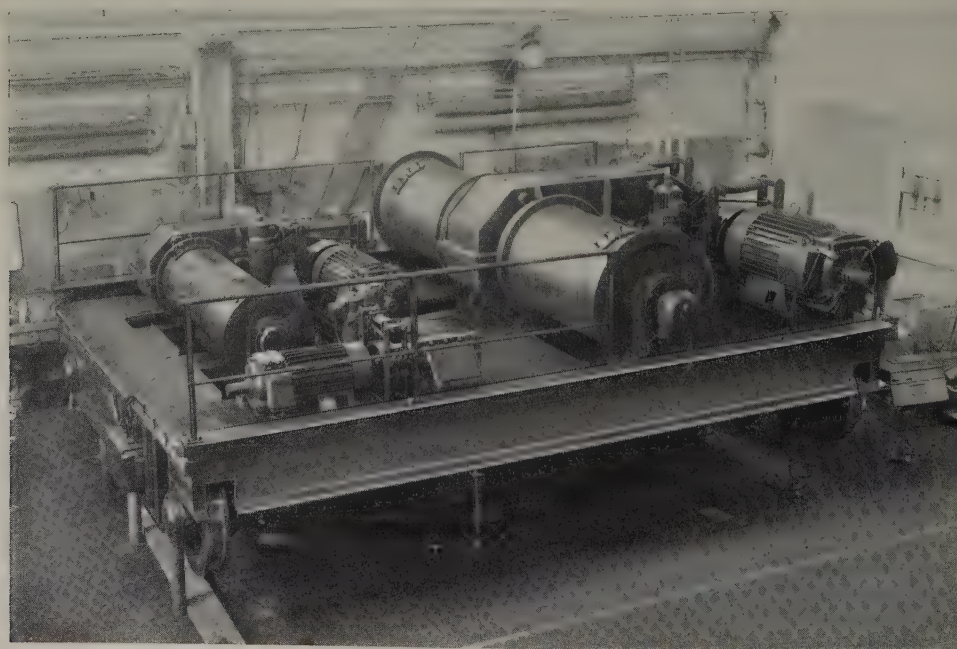
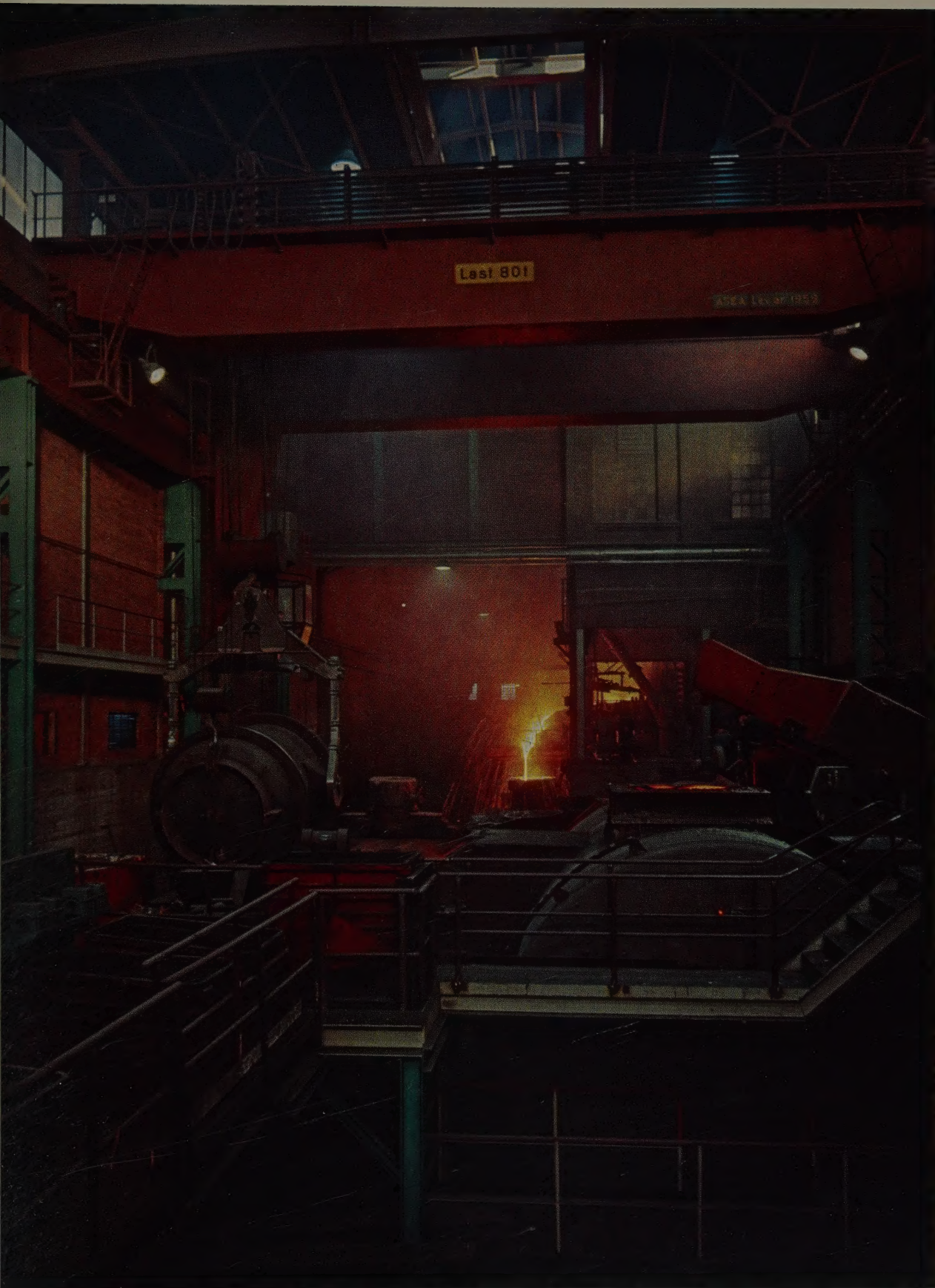


Fig. 1. The crab for an 80/16 ton ladle crane being assembled in the workshop (53799)



2. The 80/16 ton ladle crane at Hofors Bruk. (F 722)



(Z 12857)

NEWS IN BRIEF

AUSTRALIAN TRADE FAIR ON BOARD M/S KIRRIBILLI

During the summer of 1961, a floating export trade fair was arranged on board the M/S Kirribilli during a journey through Australia where, amongst other places, the following ports were visited: Fremantle, Adelaide, Melbourne, Sydney, Newcastle and Brisbane. At the visits in various ports, press conferences were arranged and exhibitions were held for specially invited persons. Asea took part in the trade fair and displayed, amongst other things, the type MAD motor (which was later transferred to the Sydney Trade Fair, see below) as well as photographs of generators, transformers, blast circuit-breakers, mine hoists and sugar centrifugals.

Asea Reg. 9



(Z 12848)

THE SYDNEY TRADE FAIR 1961

Asea took part in the Sydney Trade Fair, held between 1st and 12th August, through the agency of its representative in Australia, Asea Electric (Aust.) Pty Ltd. The Swedish pavilion, which housed the Asea exhibits, consisted of a glass hemisphere kept up by air maintained at a pressure slightly above atmospheric. The entrances and exits were provided with swing doors with air seals. The Asea stand contained, amongst other things, induction motors (of which the type MAD motor was transferred from the Australian Trade Fair on board M/S Kirribilli, see above), lightning arresters and models and photographs of mine hoists, steam turbines and generators. The trade fair was visited by over a million persons and so much interest was shown in the displays that it was decided that a new and larger trade fair would be held at the same place in 1962.

Asea Reg. 9

REGULATION OF THE LINE LOAD BETWEEN NORWAY AND SWEDEN

the Nea Power-station of the Trond-
n Electricity Authority, equipment
load-frequency control corresponding
a "network regulator" has recently
n supplied by Asea and taken into
vice.

exchange of power, mainly constitut-
power delivery to Sweden, is effect-
via a 220 kV tie-line between Nea
ver-station in Norway and Järpen
ver-station in Sweden.

e line load is controlled automatically
the regulating equipment. Nea Power-

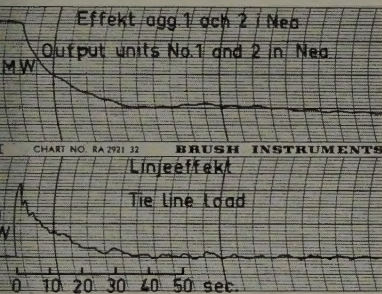


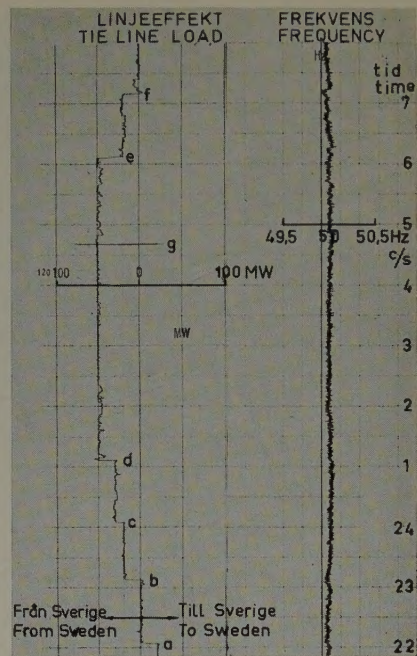
Fig. 1. Disconnecting 45 MW of gene-
rator output in the Norwegian network.
(12523)

Fig. 2. Regulation of the line load be-
tween Norway and Sweden. Regulating
strength 100 MW per c/s. The regulating
programme was changed at the times
marked a-f. (Z 12524)

station is equipped with Asea electro-
hydraulic turbine governors which can
easily be adapted for various forms of
secondary control. Therefore, relatively
little extra equipment is required for
line-load regulation.

The electro-hydraulic governor principle
allows of rapid and continuous regula-
tion as illustrated in Fig. 1 which shows
the governor action when a 45 MW ge-
nerator output in the Norwegian net-
work is disconnected. The line load is
restored to the correct value after about
30 seconds, and a completely aperiodic
curve is obtained.

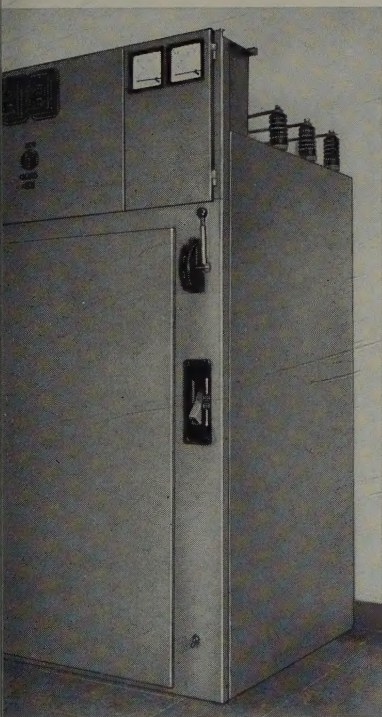
Fig. 2 shows the line load and network
frequency during normal service 27-28.
4.61. At the times a-f, the programme
for the power exchange was altered.
The ripples in the output curve are due
to the influence of the frequency regula-
tion which was set at the value 100
MW per c/s. This value ensures fre-
quency regulation within the Norwegian
network if the link with the Swedish



network should be broken. At point g,
a large instantaneous disturbance caused
by arc furnaces occurred.

The regulation principle is described in
Asea Pamphlet 7380 Ea.

Asea Reg 527



(55309)

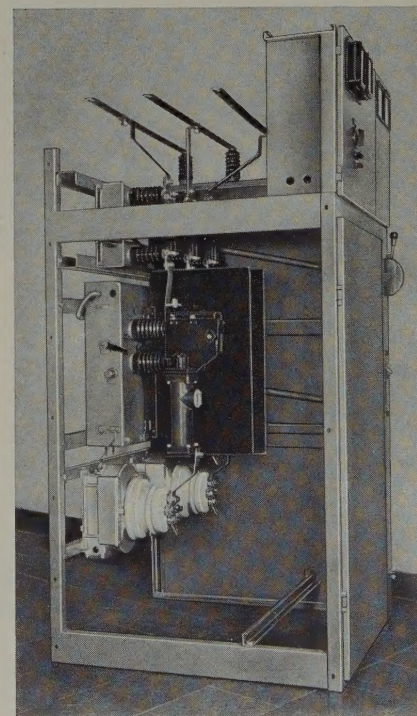
SWITCHGEAR FOR 10 kV

The new Asea 10 kV standard switchgear
unit of type VHDA 10 E is of simple
design and is mainly intended for the use
of industrial consumers and for trans-
former stations and small power-stations.
The switchgear is provided with single
busbars and the design will withstand a
short-circuit power of 350 MVA at 10 kV.

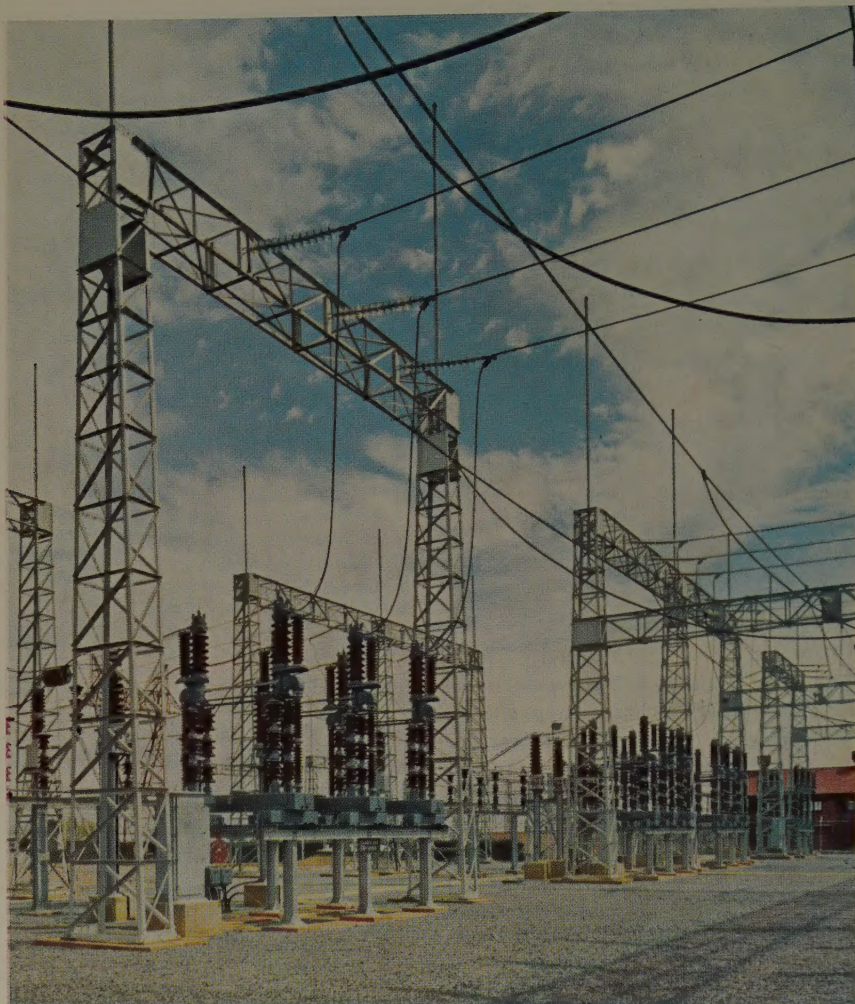
All the cubicle components are produced
in series and the various standard cubi-
cles can be ordered in prefabricated sets
which can easily be assembled either in
a workshop or on the actual site. The
illustration shows a cubicle with a 10 kV,
400 A isolator (type NDG 310/400) and
a manually operated oil-minimum circuit-
breaker (type HKL 12/400) rated at
12 kV, 400 A.

The relays and instruments are located on
a built-on control cabinet, which forms
a separate and portable unit. This ar-
rangement facilitates the erection of the
control equipment.

Asea Reg. 5860



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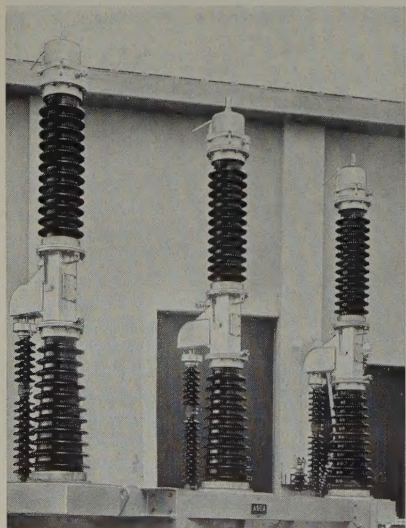


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DELIVERIES OF CONTROL EQUIPMENT TO SOUTH AFRICA

Since 1957, Asea have received orders for a combined total of about 50 contraction-type circuit-breakers (type HKEYC

120/802) for the South African 132 kV network. The circuit-breakers, which have a rated breaking capacity of 3,500 MVA at 132 kV, are designed with two breaks connected in series per phase. They have been used in those stations which have been built in recent years in the Far West Rand area. The coloured illustration shows circuit-breakers of this kind and isolators (type NSYA 120/800) installed in the West Witwatersrand Distribution Station.



(53003)

In addition to the 132 kV equipment, the deliveries have also comprised circuit-breakers and isolators for 88 kV – a voltage which led to the development of a new circuit-breaker known as HLE 88/800, see the picture alongside. This circuit-breaker has a rated breaking capacity of 1,500 MVA at 88 kV and an insulating level corresponding to an impulse test voltage of 485 kV.

A large number of 275 kV isolators of type NSYA have also been supplied to customers in South Africa.

Asea Reg. 54

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Articles or extracts from this Journal may be reprinted on condition that the name – Asea Journal – is clearly stated.

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